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CONTRIBUTIONS IN MATHEMATICS, PHYSICAL AND BIOLOGICAL SCIENCES

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INSTRUCTIONS TO AUTHORS

Three numbers of the Journal are published every year, in April, August and December respectively and contributions for publication should be sent to the Editor not later than February 1, June 1, and October 1 respectively.

Contributors are requested to be clear and concise. Manuscripts should not exceed 8,000 words and should be in a final form for the press. Each paper should start with a short summary which should be an abstract of the whole paper, complete and clear in itself, and not over 3 per cent. of the length of the paper. The introduction and reviews of literature should be restricted to closely pertinent papers.

The manuscript should be typewritten on one side of the paper only, with wide margins and be double spaced throughout including titles, footnotes, literature citations and legends. Symbols, formulae and equations must be written clearly and with great care. Scientific names of genera and species are printed in italics and should be underlined in the typescript. Too many tables, graphs, etc. should be avoided. Each table should be typed on a separate sheet with its proper position marked in the text in pencil.

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References:

Raman, C. V. (1949) The theory of the Christiansen experiment. *Proc. Indian Acad. Sci.*, A, 29: 381-90.

Sahni, B. (1936a) Wegener's theory of continental drift in the light of Palaeobotanical evidence. *J. Indian bot. Soc.*, 15: 31-32.

Sahni, B. (1936b) The Karewas of Kashmir. *Curr. Sci.*, 5: 10-16.

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Communications should be addressed to Professor T. S. Sadasivan, Editor, Journal of the Madras University (Section B), University Botany Laboratory, Madras-5, India.

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Pelagic Copepoda of the Madras Coast

BY

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(*University Zoology Laboratory, Madras-5*)

(Received for publication, March 10, 1953)

SUB-ORDER: *CALANOIDA*
Family: CALANIDAE
Genus: *Nannocalanus Sars*
Nannocalanus minor (*Claus*).

(Wilson, 1932a. P. 22, Fig. 9).

Occurrence: This copepod is never very common and has been taken in the plankton collected in July at Madras. About ten females have been taken.

Distribution: "This species has a wide distribution throughout the tropical and temperate regions of all three oceans, Pacific, Indian and Atlantic and ranges from about 33°N. in Atlantic to 50° S. in the Pacific ocean." (Sewell, 1947).

Size: Length Female 1·5 mm.

Colour: Transparent with red pigment inside the body.

Salient features: Anterior end of cophalosome rounded. The basal 2 segment bears an articulated spine on its distal external angle in legs 2 and 3 and is produced into spine like process in leg four. Basipod of fifth leg with inner margin serrate.

Sewell (1929) has recorded the occurrence of two varieties based on the difference in size—*forma major* (above 2 mm.) and *forma minor* (1·5 mm.). The present form agrees with Sewell's *forma minor*.

Genus: *Canthocalanus* T. Scott.

Canthocalanus pauper (Giesbrecht).

Occurrence: This is one of the common copepods of Madras as well as of Krusadai plankton in November-December when it occurs in large numbers.

Distribution: Widely distributed in the Pacific, Indian and Atlantic Oceans.

Size: Length Female 1·2 mm. Male 1·0 mm.

Colouration: Colourless and transparent.

Salient features: Body very robust; Anterior as well as the posterior margin of cephalothorax rounded; A 'hook' is present at the apex of the first exopod joint of the first swimming feet. The left exopod of the fifth leg of the male bears a modified clasping (?) joint.

Remarks: Up to the present time it has not been recorded from the Atlantic and Sewell (1947, p. 16) says "It would thus seem probable that this species has made its way into the Mediterranean sea from the Red Sea through the Suez Canal, though Gurney (1927) only records it from Suez Bay and the Southern end of the Canal."

Canthocalanus pauper var plumulosus (*Wolfenden*)

Occurrence: A number of *C. pauper* showing this variation in the caudal setae were present in the plankton collected at Krusadai on 11-11-1938.

Distribution: This has been recorded from the Maldives, and the Gulf of mannar.

Salient features: The caudal setae show a more or less dichotomous branching repeated in the sub-branches, the whole forming a sort of mesh. Wolfenden (1905) proposed the name '*Plumulosus*' for the variety showing this modification. In all other respects it agrees with *C. pauper.*

Genus: *Neocalanus* Sars

Necocalanus gracilis (Dana)

(Van Breemen 1908. p. 10-11 Fig. 7).

Occurrence: This is the first record of the occurrence of this copepod at Madras. Large numbers of females of this species were present in the townet collection made at Madras Harbour on 26-7-'45.

Distribution: Widely distributed in the Pacific, the Indian and the Atlantic Ocean.

Size: Length 3·0 mm.

Colour: When the copepod is alive, the body is colourless and transparent. The setae of the mandibular palp and maxillae

are deep vermillion in colour. Frequently bands of varying shades of red are present on the dorsal side.

Salient features: Anterior end of cephalosome slightly tapered. Posterior corners of cephalothorax rounded. Abdomen composed of four joints. Antennule nearly twice the length of the whole animal. The setae on the outer-margin of the exopods of the first swimming feet curved and plumose. The basal 2 bears a long, curved, plumose seta at the base of the endopodite.

Genus: *Undinula* A. Scott.

Undinula vulgaris Dana.

(Wilson, P. 29-30. Fig. 14, 1932a).

Occurrence: This is one of the largest copepods of the area under consideration. The author has found this common in Madras Plankton from October, reaching its maximum concentration in December. In Krusadai area also this appears to reach the maximum concentration in December. Two varieties, *U. valgaris var giesbrechti* Sewell and *var typica* Sewell occur here. *var giesbrechti* of Sewell (1929 p. 31) is commoner of the two varieties.

Distribution: This has been recorded from the Pacific, Indian and Atlantic Oceans.

Colouration: Varying shades of red. Those infected by helminth parasites are of uniform deep red colour.

Salient features: Anterior end of the cephalothorax rounded; posterior corners rounded or produced into one or two spinous processes based on which Sewell (1914) has created three varieties. All the members of this genus are characterised by the second joint of the second exopod being deeply notched in both the sexes. Fifth leg in the male highly modified.

(a) *Undinula vulgaris var giesbrechti,* Sewell:

Length: Female 2·5 mm. Male 2 mm.

The posterior end of the left thoracic margin of the female is thickened and ends in two spines, one directed downwards and the other horizontally (Fig. 1).

(b) *Undinula vulgaris var typica,* Sewell:

Length: 2-00 mm. Female.

The posterior margin of the cephalothorax ends in a well marked, backwardly pointed spine. This condition occurs only in the female (Fig. 2).

Remarks: According to Sewell (1929) "this is one of the most common species in Indian waters."

A single female with more than 500 larval cestodes was found on 15-11-1948.

Undinula darwini (Lubbock).

(Brady 1876. p. 54. Pl. XVI. Figs. 1-4, 6-14).

Occurrence: This copepod occurs in December in Madras waters and in December and January at Krusadai.

Distribution: This is known from the Pacific, Indian and Atlantic Oceans.

Length: Female 2·5 mm. Male 2·0 mm.

Colour: Of a light reddish colour.

Salient features: Cephalothorax rounded anteriorly and posteriorly. The third exopod joint of the third swimming leg armed with teeth on the distant end. Abdomen four jointed in the female and five jointed in the male. Right fifth foot of the male prehensile and developed into a complicated grasping apparatus. Basipod of left fifth foot armed with teeth on the inner side.

Family: EUCALANIDAE.
Genus: *Eucalanus* Dana.
Eucalanus attenuatus (Dana).

(Van Breemen, 1908, p. 16, Fig. 12).

Occurrence: This copepod is present throughout the year in Madras as well as Krusadai plankton, but never in large numbers. This reaches its maximum concentration in Krusadai waters in November.

Distribution: Widely distributed in the Pacific, Indian and Atlantic Oceans.

Size: Length Female 4·0 mm. Male 3·0.

Colour: Transparent, with varying degree of red pigment scattered about the body especially the mouth parts.

Salient features: Females of this species can be easily identified by the "triangular head with indentations on either side of the frontal margin." The abdomen is three jointed. The genital segment is longer than broad. In the male, the head is triangular in shape but the marginal indentations are not present. Abdomen is four jointed.

Eucalanus crassus, Giesbrecht.

(Van Breeman, 1908, Fig. 13).

Occurrence: This copepod is present throughout the year in the Madras as well as Krusadai plankton, but is very common from October to February in Madras and April to November in Krusadai.

Distribution: Widely distributed in all the great Oceans of the world.

Size: Length of Female 3·0 mm. Male 2·5 mm.

Colour: With varying degrees of red and orange colour scattered about on the body. Oil globules generally present inside the body.

Salient features: Females can be easily distinguished by the three jointed abdomen and the very swollen genital segment. In the male, the abdomen is four jointed. There are two bristles laterally on each side of the fourth thoracic segment.

Eucalanus elongatus. (Dana).

(Wilson, 1932a. p. 31, Fig. 15).

Occurrence: This is one of the largest copepods of this area and is found in the plankton in January.

Distribution: Widely distributed in the Pacific, Indian and Atlantic Oceans.

Size: Length of Female 5·5 mm. Male 3·8 mm.

Colour: Transparent and colourless. Mouth parts are deep violet in colour.

Salient features: This copepod can be easily identified by its large size alone. Cephalon triangular. A spine is present on the posteriolateral corner of the fifth thoracic segment of the Atlantic form but is absent in Indo-Pacific form. Abdomen four jointed in female and five jointed in male.

Eucalanus subcrassus, Giesbrecht.

(Giesbrecht, 1893, P. 132. Taf. 11, Figs. 6, 14, 19, 30, 34, Taf. 35. Fig. 12, 16, 31, 32).

Occurrence: This copepod has been taken in large numbers from October to May in the Madras plankton. It is very common in the plankton collected at Krusadai in February.

Distribution: This copepod is known to occur in the Red sea, Indian ocean, Maldives, Ceylon Pearl Banks, South African seas, Malay Archipelago, Gulf of Mannar, Bay of Bengal, off Malabar coast, Madras, and the Krusadai Islands.

Size: Length Female 2·5 mm. Male 2·4 mm.

Colour: Transparent and colourless. Red pigment scattered about on the cephalothorax.

Salient features: Anterior end of cephalon rounded. Genital segment broader than long. Proximal segment of the copepod of the antenna three times longer than broad. Second basipodite segment of the first maxilla carries five bristles as it does in *E. pilleatus, E. attenuatus, E. pseudoattenuatus* and *E. elongatus.*

Genus: *Rhincalanus* Dana.
Rhincalanus cornutus Dana.

(Wilson, 1932a. p. 33-36, Fig. 10).

Occurrence: Numerous examples of this species (all females) were found in the plankton collected off Shingle Island in the Gulf of Mannar.

Distribution: The Pacific Ocean, Bay of Bengal, Arabian Sea, Red Sea, and the Tropical Atlantic.

Length: Female 3·2 mm.

Colouration: Formalin preserved forms were light red in colour.

Salient features: Frontal process long and "anchorshaped". First antenna a little longer than the body. The ends of the thoracic segments drawn out acutely. Three pairs of small spines are present on either side of the mid-dorsal line on thoracic segments 2, 3 and 4. Fifth leg of female three segmented, the terminal segment being produced into a pointed process on the outer side and a plumose seta is present on the inner side.

Remarks: Sewell (1929) states that this copepod though appearing fairly permanently at the surface, "attains its greatest density at some distance below the surface."

Genus *Mecynocera* Thompson.

Mecynocera clausii Thompson.

(Wilson 1932a. p. 36-38. Fig. 20).

Occurrence: This is the first record of its occurrence at Madras and is present in the plankton in January and in July but never numerically strong.

Distribution: This has a wide distribution in tropical seas, and has been recorded from Pacific, Indian and Atlantic Oceans and the North Sea.

Size: Length Female 1 mm. Male 1 mm.

Colour: Transparent and colourless.

Salient features: Body elongate and slender; anterior end of cephalosome triangular in shape with indentations on the sides. The first antenna is about 2½ times longer than the animal. In the male the abdomen is four jointed and in the female three jointed.

Remarks: This can be easily identified by the enormously long antennule.

Family: PARACALANIDAE.
Genus: *Paracalanus* Boeck.
Paracalanus parvus (Claus).

(Wilson, 1932a, p. 38. Fig. 21).

Occurrence: This calanoid enjoys a world-wide distribution.

Size: Length Female 0·629. Male 0·50.

Colour: Transparent and colourless. Sometimes slightly reddish.

Salient features: Short stout body with the anterior end of Cephalosome more or less rounded with two rostral filaments. The outer margins of the exopods of swimming feet armed with teeth. The females are easily distinguished by the two jointed fifth leg the free joint bearing two unequal setae. The males are distinguished by the very short genital, segment, six jointed exopod of second antenna and uniramous fifth leg with a two jointed right and a five jointed left leg.

Remarks: This copepod is present throughout the year in Madras as well as Krusadai plankton, but very scarce in July while reaching its maximum in September. A single haul made on 8th September, 1937 in K. Channel contained as many as 1950 specimens.

Paracalanus aculeatus, Giesbrecht.

(Wolfenden, 1906, p. 998. pl. xcvi. Figs. 12-15).

Occurrence: This copepod which has a wide distribution occurs from September to May in the Madras as well as Krusadai waters.

Distribution: The Pacific Ocean, Bay of Bengal, Indian Ocean, the Arabian Sea, Red Sea and the Atlantic Ocean.

Size: Length of female 1·2 mm. Male 1·0 mm.

Colour: Colourless and transparent. Sometimes dirty yellow in colour.

Salient features: Animal small and robust. The antennule long reaching upto the anal segment. Endopodite joint of the fourth swimming feet with spinules. Fifth leg two jointed in female, five jointed in the male.

Remarks: This copepod can be easily identified by its larger size and the longer antennule.

Genus *Acrocalanus Giesbrecht.*

Acrocalanus longicornis Giesbrecht.

(Wolfenden, 1906, p. 1000. Pl. xcvii. Figs. 23 & 24)

Occurrence: This is one of the commonest copepods of this area and has been taken almost throughout the year.

Distribution: The Pacific and the Indian Oceans, Bay of Bengal, Arabian Sea, Tropical and temperate Atlantic.

Size: 1·2 mm. female.

Colour: Transparent and Colourless.

Salient features· Cephalosome arched on the dorsal side. Antennule projects over the end of the abdomen by five joints. The distal part of the last joint of the exopodite of the fourth pair of swimming feet armed with very fine teeth. Fifth leg usually absent but rudimentary occasionally.

Remarks: Sewell (1929) has given a detailed description of the male of this copepod. He considers A *gardineri* Wolfenden to be the male of *A. longicornis.*

Acrocalanus gibber Giesbrecht.

(Gurney 1927, P. 147, Fig. 18).

Occurrence: This is the first record of the occurrence of this copepod at Madras. It is common in July and September in the Madras as well as Krusadai plankton.

Distribution· The Pacific ocean, Indian Ocean, Bay of Bengal, Arabian Sea, Red Sea and Suez Canal.

Size: 0·85 mm. long (female).

Colour: Often with red pigment inside the body.

Salient features: Body compact. Cephalosome is oval in shape. Has a peculiar dorsal hump. Antennule of moderate length reaching up to the furca. The proximal part of the exopodite of the third swimming feet longer than the distal part and carrying spinules. The furca at 45° to the anal segment in the male. Fifth leg present on the left side only five jointed in the male.

Remarks: This copepod can be easily identified by its smaller size, dorsal hump and shorter antennule.

Acrocalanus gracilis Giesbrecht.

(Wolfenden, 1906, p. 1003, pl. xcvii, Figs. 2, 7).

Occurrence: This copepod has been taken in November at Madras.

Distribution: The Pacific Ocean, Indian Ocean, Bay of Bengal Arabian Sea, Red Sea and Gulf of Suez.

Size: 1·14 mm. Female.

Colour: Transparent and colourless.

Salient features: Dorsal surface smoothly curved when viewed from the side. There is no dorsal hump. Antennule long. Distal part of the outer margins of exopodite of the fourth swimming feet with stout teeth. Fifth leg rudimentary.

Remarks: This copepod can be easily identified by its larger size and oval shaped cephalosome without the dorsal hump.

Acrocalanus monachus Giesbrecht.

(Wolfenden 1906. p. 1002, pl. xcvii, Figs. 27, 28).

Occurrence: K. S. Menon (1930) claims this is to be the commonest Acrocalanid at Madras. This occurs from October to April.

Distribution: The Pacific Ocean, the Great Barrier Reefs, Malay Archipelago, Bay of Bengal, Madras, the Ceylon Pearl Banks, the Maldive Archipelago, Arabian Sea, South Africa.

Size: 0·91 to 0·92 mm. (Female).

Colour: Red pigment inside the body.

Salient features: Cephalothorax broad and truncate, almost quadrate in shape (in lateral view). A small and compact form. Genital segment slightly swollen towards the ventral side.

Remarks: This copepod can be easily identified by the cephalosome with a dorsal hump.

Family: PSEUDOCALANIDAE.
Genus: *Clausocalanus* Giesbrecht.
Clausocalanus arcuicornis (Dana).

(Esterley, 1924, p. 89, Fig. c. 1-18).

Occurrence: This is the first record of its occurrence at Madras. This is present in the plankton at Krusadai as well as Madras from July till December.

Distribution: It is widely distributed in all the great oceans of the world.

Size: Length female 0·96.

Colour: Transparent and colourless. Sometimes slightly pinkish.

Salient features: Anterior end of cephalothorax rounded; antennule reaching as far as the posterior end of cephalothorax. Endopod of second swimming feet two segmented. Abdomen four jointed. Fifth leg in the female two jointed, the end with bifid tips.

Remarks: Fruchtl (1923), Farran (1926) and Sewell (1929) have drawn attention to the existence of two forms mainly differing in sizes. Here at Madras, *forma minor* of Sewell occurs.

Farran (p. 24, 1920) states that *C. arcuicornis* is one of the Oceanic species of such regular occurrence that they "might almost be used to measure the average salinity."

Genus: *Calocalanus* Giesbrecht.
Calocalanus pavo (Dana)

(Wilson, Fig. 22, 1932).

Occurrence: This has been taken in the plankton throughout the year but is not very common except in January.

Not a single specimen was found in the entire collection from Krusadai.

Distribution: This has a wide distribution in the Pacific and Indian, and Atlantic Oceans, the Bay of Bengal, Arabian Sea, Red Sea, the Adriatic Sea, and the Mediterranean Sea.

Size: Length Female 0·86 mm.

Colouration: Cephalothorax varies from deep red to shades of red and the caudal remii are dirty yellow or colourless.

Salient features: Anterior end of cephalosome slightly tapered. Abdomen two segmented and the furcal ramii horizontal and at right angles to the abdominal joints, which character alone is sufficient to identify this species.

Remarks: None of the forms present here had the antennule in full and in most of the specimens it was cut at some length or other. The caudal setae were never intact and only "stumps" were left. "The Caudal setae and antennule appear to be, in this species, more than usually fragile" as remarked by Scott, T. (1894). The presence of early copepodite stages in the development of this is a common feature of the plankton in January.

Family: EUCHAETIDAE.
Genus: *Euchaeta* Phillipi.
Euchaeta marina (Prestandrea)
(A. Scott, 1909, P. 67. Pl. XIX. Figs. 9-20).

Occurrence: This is the first record of the occurrence of this copepod off Madras. This copepod occurs sparingly in November and January.

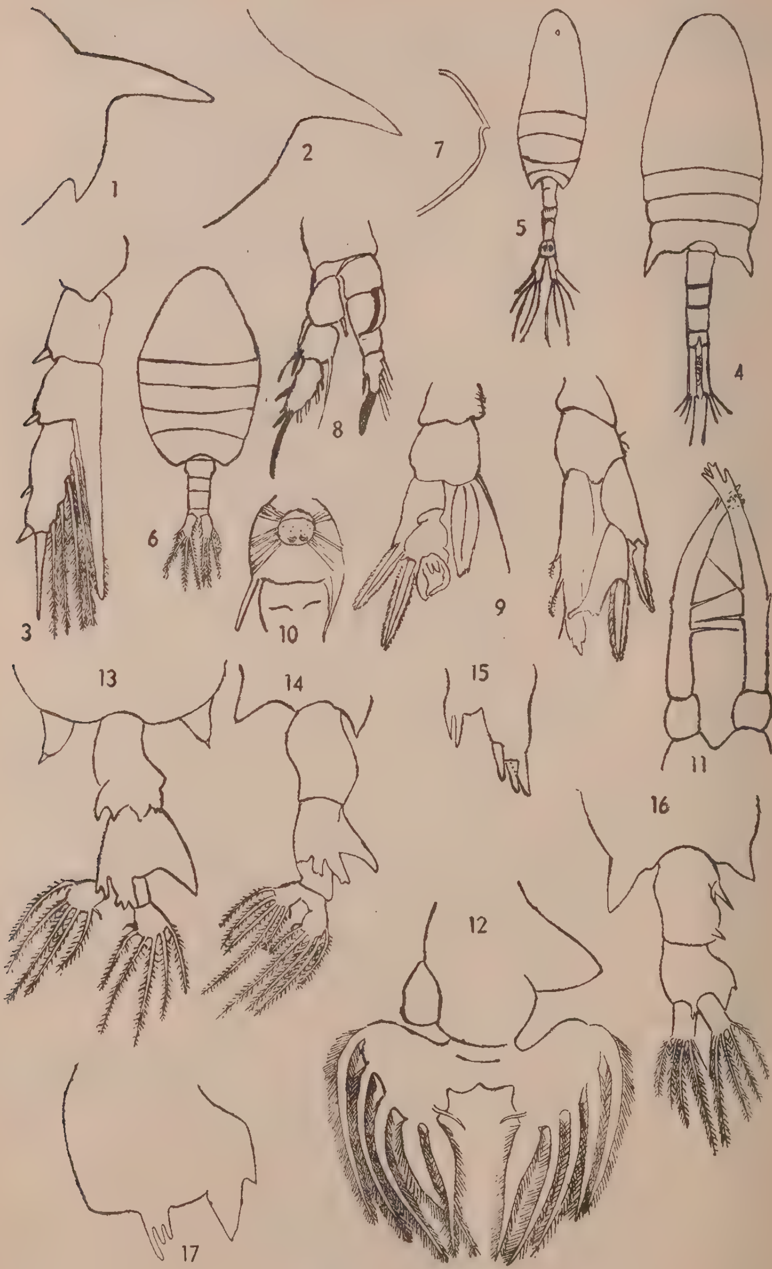
Distribution: The Pacific, Indian and Atlantic Oceans, the Bay of Bengal, the Arabian Sea, Red Sea and the Mediterranean.

Size: Length Female 3·3 mm. Male 2·5 mm. (Immature).

Colouration: Cephalothorax is of a light red colour with bends of deep red and orange markings, usually in alternating bands. The eggs are of a deep blue colour.

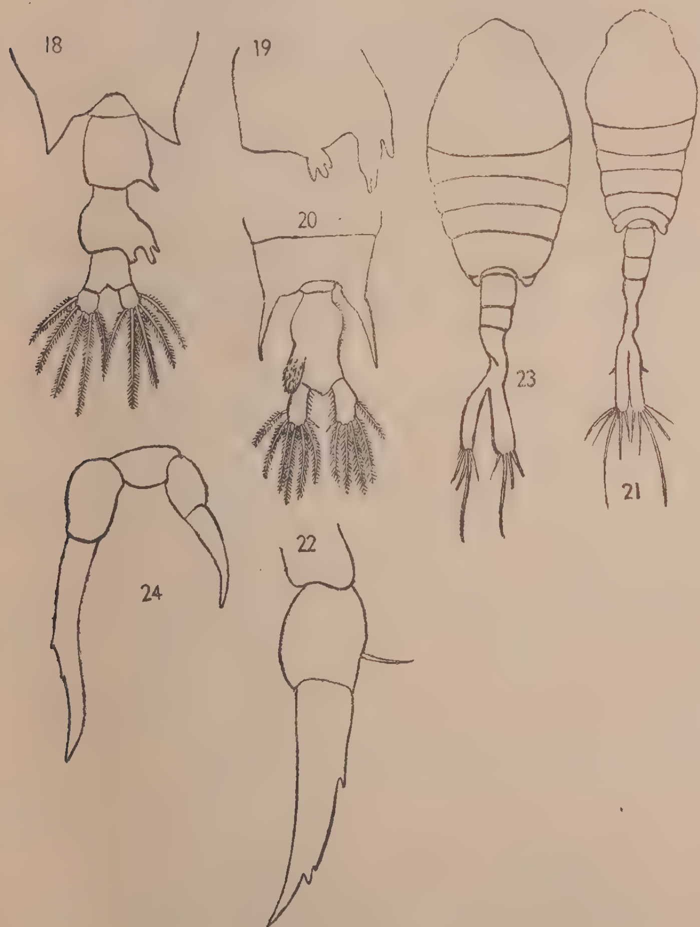
Salient features: The anterior end of cephalothorax produced into a knob like projection above the rostrum. First antenna is long and reaches as far as the second abdominal segment. The genital segment is asymmetrical in female, the right side with a projection. In the male the genital segment is symmetrical.

Family: CENTROPAGIDAE.
Genus: *Centropages* Herrick.
Centropages furcatus (Dana).
(Brady, 1882, p. 83 pl. xxviii).



Text Figs. 1—17

Occurrence: This occurs throughout the year in Madras and Krusadai and is very common from January to April.



Text Figs. 18—24

Distribution: This seems to have a wide distribution in tropical areas.

Size: Length Female 1·9 mm. Male 1·4 mm.

Colouration: Transparent sometimes of dirty green with bands of greenish brown are seen on the dorsal side of cephalothorax, Eye of ruby red colour.

Salient features: Anterior end of cephalothorax square-shaped the posterio-lateral margin being produced into two lateral acute processes. Eye of composite structure and capable of rotatory movement. The inner margin of the second exopod joint of fifth leg in female is produced into a spine and is armed with small teeth. In the male, the 'chela' on the right fifth leg is prominent and without any setose hair on it.

Centropages dorsispinatus Thompson & Scott.

(Thompson & Scott, 1903, pl. I, Fig. 15-20)
(Centropages notoceros Cleve 1903)

Size: Female 1·4 mm. Male 1·25 mm.

Occurrence: This is present in the plankton from August to April reaching its maximum in October.

Distribution: This seems to be largely confined to the east coast of India and has been recorded from Malay Archipelago, Ceylon Pearl Banks, Gulf of Mannar, Bay of Bengal, Madras. Cleve has recorded this as *C. notoceros* from the Arabian sea off Karachi.

Colour: Light green colour, red pigment is found scattered about the cephalothorax as well as the abdomen. A dark red spot is found in the region of the 'dorsal hook'.

Salient features: Anterior cephalothoracic margin rounded and the posterior margin produced into acute process. A curved hook is borne medially by the cephalosome. Abdomen three segmented in the female, the genital segment is very swollen. The projection of the fifth leg without any spines or hairs. The outer margin of 'chela' of the fifth leg of male hirsute.

Remarks: This species can be easily identified by the dorsal hook.

Centropages tenuiremis Thompson & Scott.

(Thompson and Scott, 1903, pl. I. Fig. 14 to 18).
(Syn. *Centropages arabicus.* Cleve 1903).

Occurrence: This species occurs from October to March in Madras and from January to March in Krusadai.

Distribution: This seems to be confined to Indian seas and has been recorded from the Arabian sea and Ceylon Pearl Banks, Gulf of Mannar, Burma Coast, Madras and off Puri, Bay of Bengal.

Size: Length of Female 1·8 mm. Male 1·45 to 1·6 mm.

Colouration: Dirty green in colour. Sometimes the abdomen is of a yellow colour. Patches of dirty brown are found on the cephalothorax. Eye red in colour.

Salient features: Anterior end of cephalothorax slightly pointed, posterior margin tapered into acute process and divergent. Abdomen three jointed in female and four jointed in male. The spine of the exopod of fifth leg armed with teeth.

Remarks: While the specimens from Ceylon Pearl bank measured 2·0 mm. (female) and 1·8 mm. (male), the Madras forms were smaller measured 1·8 mm. (female) and 1·45-1·6 mm. (male). Sewell (1932) records the length of the specimen caught off Puri in the Bay of Bengal as 1·71 mm. (female) and 1·4 mm (male). According to him this difference in size may be due to the variation in salinity.

The early copepodites are common in February and March in Madras as well as Krusadai plankton.

Centropages trispinosus Sewell. (Figs. B & C).

(Sewell 1914, p. 223-224. pl. xviii. Figs. 3-8).
(Krishnaswami, 1951, p. 76 Fig. 2).

Occurrence and distribution: This species was founded by Sewell in 1914 on the basis of a single female taken at Kilakarai in the Gulf of Mannar.

Size: Female: Total length 1·4-1·6 mm. 1·025 mm. male.

Colouration: Of yellowish red colour. Dark red patches are seen on the cephalothorax. A bright red spot is present on the anal segment.

Remarks: This species can be easily identified by the presence of three spines of the posterior end of the cephalothorax. The occurrence of this at Madras is of interest because it was previously known only from Kilakarai.

Centropages calaninus (Dana)

(Giesbrecht, p. 305. pl. 17, 18 & 38, 1892).

Occurrence: This is the *first record* of the occurrence of this copepod at Madras. This occurs from September to January in Madras Plankton in small numbers.

Distribution: The Pacific, the Great Barrier Reefs, the Malay Archipelago, the Bay of Bengal, the Ceylon Pearl Banks, the Lac-

adives and Maldives, the Arabian Sea, the Red Sea, Suez Canal, the South Atlantic Ocean.

Size: Length Female 2 mm.

Colouration: Of uniform orange colour. The caudal setae lighter in colour.

Salient features: Anterior end of the cephalothorax broadly triangular and posterior thoracic corners broadly truncate. Anal segment is slightly asymmetrical and longer than any other obdominal segment. The projection on the second exopod of the female fifth leg nearly straight and extends beyond the distal end of the third joint and is slightly 'ciliated' at the tip (Fig. 3) large in size.

Centropages orisinii Giesbrecht.

(Wolfenden, p. 1015, pl. xcviii, Figs, 1, 4, 5, 11 & 12, 1906).

Occurrence: This copepod occurs between January and April in Krusadai. It is never very common in Madras plankton, being found only in the month of March.

Distribution: The Pacific, Indian and Atlantic Oceans.

Size: Length female 1·6 mm. Male, 1·3 mm.

Colours Light yellow. Sometimes transparent and colourless.

Salient features: Anterior end of cephalothorax rounded; posterior end slightly produced into a spinous process. Abdomen three jointed in the female. Anterior antenna reaching as far as the furca. Spine of the right exopod in female, curved and armed with small teeth, that of the left with fine serrations. Abdomen four jointed in the male. Antennule geniculate.

PSEUDO-DIAPTOMIDAE

Genus: *Pseudodiaptomous* Heerick.

Pseudodiaptomous aurivilli Cleve, (Fig. 4).

(Thompson and Scott, 1903, Pl. 11, Figs. 24 to 26).

Occurrence: This is the first record of the occurrence of this copepod, on the Madras coast. Large numbers of this are found from July to January in Madras as well as Krusadai plankton.

Distribution: This seems to be confined to the Indo-Malayan region as it has been recorded from the Malay Archipelago, Ceylon Pearl Banks, Gulf of Mannar and Bay of Bengal.

Size: Female 1·2 mm. Male 1 mm.

Colour: The cephalothorax with alternating bands of yellow and green or brown. The geniculate antennule of the male is of a light yellow colour.

Salient features: The anterior end of cephalothorax evate while the posterior corners are produced into acute processes. The sides of the cephalothorax are almost parallel. This abdominal joints are denticulate. Caudal furca longer than broad. Fifth leg two jointed in the male. The right antennule is geniculate in the male.

Remarks: This appears to breed in August and December when large numbers of this are found in copula. It is not uncommon to find more than two males clinging on to a single female.

Genus: *Schmackeria* Poppe and Richard 1890

Marsh (1933) has revived this genus to include the Pseudodiaptomous species in which the "second segment of the basipod of the left fifth foot of the male is armed; and its inner border with a long curved projection," and in the last thoracic segment of the female being rounded. The following species, according to Marsh should be transferred to this genus. *P. smithi, P. tolligeri, P. poppei, P. annandalei, P. serricaudatus, P. inopinus, P. binghami,* and *P. lobipes.* Only two species of this occur in Madras.

Schmackeria serricaudatus (T. Scott) (Fig. 5).

(Marsh, 1933, p. 46-47, pl. 22, Figs. 2 & 3).

Occurrence: This is the first record of the occurrence of this copepod at Madras. It occurs in large numbers from July to December in Madras and August to April in Krusadai. This reaches its maximum concentration in Krusadai plankton in September.

Distribution: This seems to be largely confined to the Indian ocean and has been recorded from Chilka Lake, Ceylon Pearl Banks, the West coast of India, the south Arabian coast, the Gulf of Aden, the Red Sea, Cape Colony and the Gulf of Guinea.

Size: Female 1·2 mm. Male 1·15 mm.

Colour: The whole body surface is of a yellow colour patches of red are found on the cephalothorax.

Salient features: Cephalothorax more or less elliptical with the posterior corners rounded and denticulate. Abdomen four

jointed in male. In the female the genital segment is indistinctly divided, swollen and asymmetrical (Fig. 5). Abdominal segments fringed with spinules. Right antennule geniculate in male. Ovisac single.

Remarks: The Madras forms differ from the Scott's specimen in the genital segment being asymmetrical. In all other respects it agrees with the description given by Scott. Sewell (1947 p. 164) remarks "It would appear to be an Indian Ocean form that has managed to get round the Cape of Good Hope into the Gulf of Guinea, where it was originally taken."

Schamackeria annandalei (Sewell)

(Sewell, 1919, p. 5, pl. x. Fig. 9; 1924, p. 787, pl. xliv. Fig. 2).

Occurrence: This copepod is a blackish water form and has been taken in large numbers in the collections from the Cooum. Only once did a few specimens occur in the sea when the bar was open. In Krusadai it appeared in a night collection on 22-3-1949.

Distribution: Chilka Lake, Quilon, Travancore, Madras, and Krusadai Island.

Size: Female 1·2 mm. Male 1·0 mm.

Colour: Specimens preserved in formalin are of a light rose colour.

Salient features: Cephalothorax more or less elliptical with the anterior margin rounded. Genital segment with triangular lateral expansion in both the sexes. The caudal setae are very thick and spathulate. The abdomen is four jointed in female and five jointed in the male.

Remarks: This was originally described by Sewell (1919) under the name *Pseudodiaptomous annandalei* and removed to the present genus by Marsh (1935). When the bar was open few males and females were taken in the sea. This seems to breed in April when the presence of copepodites and nauplii is a regular feature of Cooum plankton.

Family: TEMORIDAE.

Genus: *Temora* Baird.

Temora turbinata (Dana).

(Wilson 1932a. p. 106-107. Fig. 71 a-e).

Occurrence: This copepod is common both at Madras and Krusadai and occurs from July to January.

Distribution: The Pacific Ocean, Bay of Bengal, the North Atlantic Ocean.

Size: Length Female 1·4 mm. Male 1·3 mm.

Colour: Dorsal side of cephalothorax has patches of bright yellow colour. The colouration is very marked at the base of the antennule and other mouth parts.

Salient features: Cephalothorax more or less oval in shape. Abdomen shorter than the cephalothorax. Caudal furac longer than the abdominal joints. The fifth leg in female two jointed the terminal joint with three apical and one sub-apical spine. In the male it is prehensile.

Remarks: This species resembles the well known form in the Northern waters, *Temora longicornis* Muller. A. Scott (1909 P. 119), considers that this "may simply be a tropical variation of the well known northern form".

Temora discaudata Giesbrecht.

(Giesbrecht, 1892, p. 328, pl. 17 and 38).

Occurrence: This copepod appears in large numbers in Krusadai plankton from January to March. At Madras this occurs from August to December but never in very large numbers.

Distribution: The Pacific Ocean, the Indian and Atlantic Oceans, the Arabian Sea and the Mediterranean Sea.

Size: Length Female 1·7 mm. Male 1·5 mm.

Colour: Transparent and colourless.

Salient features: The posterior angles of the cephalothorax produced acutely. Caudal furca asymmetrical in female and hirsute on the inner side.

Remarks: This copepod can be at once recognised by its asymmetrical caudal furca.

Temora stylifera (Dana).

(Wilson 1932a. p. 104, Fig. 69a to c).

Occurrence: This copepod which Scott claims as the most common extra European copepod is here recorded for the first time at Madras. This occurs in large numbers in Krusadai plankton from October to December, reaching its maximum in December. In Madras plankton a few specimens were taken in August and November.

Distribution: Pacific, Red Sea, Mediterranean, Arabian Sea, and Bay of Bengal.

Size: Length Female 1·5 mm. Male 1·2 mm.

Colour: Body transparent with deep yellow on the sides of cephalothorax.

Salient features: Anterior end of cephalothorax broadly truncate while the posterior corners are produced acutely. Caudal ramii nearly six times longer than wide. Fifth leg two jointed in male with three apical and one lateral spine. The left fifth leg in female is very swollen and the right with a claw bent on it.

Family: LUCICUTIDAE.
Genus: *Lucicutia* Gierbrecht.
Lucicutia flavicornis (Claus Fig. 11).

(Van Breemen, 1908, p. 112. Fig. 129a-d).

Occurrence: This is recorded for the first time from Madras. Several specimens (all males) were present in the plankton collected in July, especially on 26-7-1948 (Harbour collections).

Distribution: In the Pacific Ocean, Bay of Bengal, Atlantic Ocean and the Mediterranean Sea.

Size: Length 2·5 mm. Female.

Colouration: Formalin preserved forms appear colourless.

Salient features: Body longer than broad. The anterior end of cephalosome obtusely pointed. Antennule reaches upto the caudal furca and is densely armed with "aesthetes" which character appears to be the hall mark of this species. Abdomen four jointed. The 2nd furcal setae are longer than the rest.

Family: AUGAPTILIDAE.
Genus: *Haloptilus* Giesbrecht.
Haloptilus longicornis (Claus) (Fig. 26).

(Van Breemen, 1908, p. 128. Fig. 146).

Occurrence: This is the first record of the occurrence of this copepod at Madras. 10 females were collected from the tow-netting made at the Madras Harbour in July 1948.

Distribution: This species has a wide distribution in all great oceans of the world.

Size: Length 1·4 mm.

Colour: Transparent and colourless.

Salient features: The anterior end of cephalosome has a knob like projection. Antennule very long, twice the length of the animal. Body flattened. The endopod of antenna longer than exopod. The abdomen is composed of four segments.

Remarks: This copepod can be easily identified by the knob-like projection on the cephalosome, long antennule and the flattened transparent body.

Family: ARIETELLIDAE.
Genus: *Metacalanus* Cleve.
Metacalanus aurivilli Cleve. (Fig. 6).

(Thompson and Scott, 1903, p. 243 pl. 11 Figs. 18-20).

Occurrence: This is the first record of this calanoid in Madras. Large numbers of this were present in Krusadai and Madras Plankton throughout the year.

Distribution: This has been recorded from Malay Archipelago, Ceylon, Pearl Banks, Gulf of Mannar.

Size: Female 0·6 mm. Male 0·5 mm.

Colour: Dirty yellowish brown.

Salient features: This copepod can be easily recognised by its small size. The anterior part of the Cephalosome is obtusely pointed. Posterior corners of cephalothorax rounded. The right antennule is shorter than the left in both sexes. Fifth feet in female single jointed and in the male it is four jointed.

Remarks: Large numbers of this are present especially in the month of July. As remarked by Sewell (1914) because of its small size it is liable to be passed over unnoticed.

Family: PSEUDOCYCLOPIDAE.
Genus: *Suezia* Gurney.
Suezia sp.

(Gurney 1927. P. 457).

Occurrence: A single male of this copepod was found in Krusadai plankton dated 23-7-1938. The specimen was slightly damaged. This is the first record of the occurrence of this copepod. The only locality wherefrom it is known previously being is Suez Canal.

Size: Male 0·679 mm.

Colour: Formalin fixed specimens appear yellow.

Salient features: General body shape cyclopiform. The last thoracic segment with a small projection (Fig. 7). The basel 2 of the endopod of first leg with a curved spine (Fig. 8). Antennule not prehensile. Fifth leg highly modified and tiramous.

Remarks: The genus Suezia was created by Guruney in 1927 on the basis of two males examined from Suez Canal. The only known member of this genus in *Suezia canalis* Gurney.

In the present specimen, the left fifth leg resembles Gurney's figures exactly while the right exopod differs from it in the second joint being shorter (Fig. 9).

Family: CANDACIIDAE.
Genus: *Candacia* Dana.
Candacia pachydactyla (Dana).

(Brady 1883, p. 68, pl. xxxvi, Figs. 2-9).

Occurrence: Only females of this form have been encountered in the Madras plankton, this being the first record of its occurrence at Madras. It occurs sparingly in September and February at Madras.

Distribution: This copepod has a wide distribution and is known to occur in the all great oceans of the world.

Size: Length Female 2·5 mm.

Colour: The dorsal side of cephalothorax deep black in colour, the pigment being arranged in regular pattern. The abdomen is transparent and colourless. There are bands of black on the cephalothorax. The swimming feet are all coloured black, the intensity becoming lighter towards the inner side. The colouration differs from that given by Wilson (1932a. p. 141). He says that in the female "the body is more or less transparent and colourless except for scattering of red oil drops and reddish or yellowish oviducts. The chitin of the body especially the end segments of the second to fourth exopods and the stout spines on the fifth legs of the female, have a reddish brown wash of greater or less intensity."

Salient features: The copepod has a very robust appearance. The posterior corners of the cephalothorax are produced into acute processes. Abdomen two jointed in the female. Genital segment

is swollen and carries two processes ventrally as shown in the (Fig. 10). Fifth leg two jointed, the second joint carrying two spines and three setae like spines towards the inner side.

Remarks: This copepod can be identified at once by its striking colouration and the finger like processes in the genital segment.

Canadacia truncata (Dana).

(Giesbrecht, 1892, p. 425, pl. 21, 22 & 39)

Occurrence: This copepod is common in November and January as recorded by K. S. Menon (1930). It occurs in December in Krusadai plankton.

Distribution: This is known to occur in Indian Ocean, Red Sea, Malay Archipelago, Lacadives and Maldives, Gulf of Mannar, Bay of Bengal, Madras.

Size: Length Female 1·5 mm. Male 1·3 mm.

Colour: Transparent and colourless.

Salient features: General body form as in other members of the genus. Genital segment slightly dilated in the middle and barrel shaped. Abdomen three jointed in the female and five jointed in the male. The fifth leg is two jointed in the male, the terminal joint with three spines on the inner side towards the distal end.

Remarks: This copepod can be easily recognised by the shape of the genital segment and the fifth leg.

Candacia discaudata A. Scott.

(A. Scott, 1909, p. 157, Pl. XLVII, Figs. 10-20).

Occurrence and distribution: This is the first record of the occurrence of this species at Madras though this has been recorded from Malay Archipelago and the Gulf of Mannar and Bay of Bengal. This occurs in September in the Madras Plankton. About 20 specimens, all females were collected on 30-9-1947.

Size: Length Female 1·9 mm.

Colour: The living animal is transparent with black colour, scattered about on the dorsal surface.

Salient features: The cephalothorax is nearly twice as long as the abdomen. Genital segment with short seta on each side. Abdomen three jointed. The fifth leg is two jointed. The second joint

is long and slender and carries four coarse teeth. The left leg is longer than the right leg.

Remarks: In Scott's (1909) original description of the species he mentions his type as having a seta on the first joint and having three coarse teeth. The Madras forms differ from Scott's in having four coarsely set teeth on the left side instead of three. The right leg is normal with three coarsely set teeth (Fig. 11).

Canadacia bradyii Scott.

(A. Scott, 1909, p. 156, pl. XLVII, Fig. 1-9 Sewell, 1912)

Occurrence and distribution: This copepod occurs in large numbers in September and October at Madras and this has been recorded from Indian Ocean, Maldives and Lacadives Malay Archipelago, Ceylon Pearl Banks, Bay of Bengal, Madras.

Size: Length Female 1·8 mm.

Colour: Transparent and colourless. Formalin preserved slightly reddish brown.

Salient features: Anterior end of cephalothorax squared. The cephalothorax is nearly twice the length of the abdomen which is composed of three joints. The fifth leg of female two jointed, the second joint with two spinuous projections towards the distal end on the inner side. The abdomen is five jointed in the male.

Remarks: The female of this copepod was first described by Sewell in 1912 from Bay of Bengal. In Madras, collections both the males and the females were present.

Family: PONTELLIDAE.
Genus: *Labidocera* Lubbock.
Labidocera acuta (Dana).

(Breeman 1908, p. 150-151. Fig. 16a-b).

Occurrence: This is one of the largest copepods of the Madras coast and is present throughout the year although it is very common from January to March.

Distribution: This copepod has a wide range of distribution in tropical seas.

Size: Length Female 3·8 mm. Male 3·2 mm.

Colouration: Light green with alternate bands of dark green and brown. Eye of reddish violet.

Salient features: The rostrum is produced into an acute process which character alone is sufficient to identify this species.

Lateral hooks absent. Posterior angles of cephalothorax (uniformly) acutely produced in the female. In the male the right posterior angle is drawn out into a process. Abdomen three jointed in female and five jointed in male.

Remarks: The presence of this copepod is a regular feature in the off shore plankton at Krusadai.

Labidocera pavo Giesbrecht (Fig. 12).

(Giesbrecht, 1892, p. 27 and Sewell 1914 p. 234 pl. xxi. Fig. 1-3).

Occurrence: This is the first record of the occurrence of this copepod at Madras. This copepod appears in large numbers in the plankton collected in February and in the off shore plankton (Off Pulli Islands) collected in July 1937, in Krusadai.

Distribution: This copepod has been recorded from the Red Sea, Malay Archipelago, Ceylon Pearl Banks, Suez Canal, Gulf of Mannar, Chilka Lake.

Size: Length Female 1·7 mm. Male 1·45 mm.

Colouration: The female is of light green colour with red pigment scattered on the dorsal side of cephalothorax. The plumose caudal setae are yellow in colour. The male is deep blue in colour with bands of light blue alternating.

Salient features: The cephalosome is truncate and the posterior corners of cephalothorax are produced into acute processes. The abdomen is two jointed in the female and the right margin of the genital segment is produced into a triangular process. The caudal ramii bears five setae which are thickened at the bases (Fig. 18). The abdomen is four jointed in the male and the caudal setae are not swollen at the base.

Labidocera kroyeri (Brady).

Labidocera kroyeri was described under the name *pontella kroyeri* by Brady in his "Challenger reports' and later removed to the present genus by Giesbrecht. As remarked by Brady (1876) "This species is subject to a good deal of variation especially in peculiar distortions or outgrowths of the abdominal somites." (p. 94). From the neighbourhood of Indian waters two varieties of females *L. kroyeri var similis* Wolfenden from Maldives and *L. kroyeri var bideus* Sewell from Burma and three varieties of males *L. kroyeri var gallensis L. kroyeri var stylifera* Thompson and Scott from the Ceylon Pearl Banks and *L. kroyeri var burmanica* Sewell from Burma.

It is difficult to decide the nature of the biological phenomenon responsible for the evolution of so many varieties within a single species confined to habitats not far removed geographically nor differentiated markedly by ecological factors.

In the Madras as well as Krusadai plankton both *L. kroyeri var gallensis* and a new variety are present in large numbers.

Labidocera kroyeri var gallensis Thompson & Scott.

(Thompson & Scott, 1903, p. 251, pl. 11. Fig. 6-7).

Occurrence: This is the first record of the occurrence of this variety at Madras. This was originally described by Thompson and Scott from Pearl Banks and has been recorded from the Bay of Bengal by Sewell. About 20 specimens were collected in the plankton from December to February.

Size: Male 2·0 mm.

Colour: Light green in colour with tinges of red near the anal segment and the anterior end of cephalothorax.

Salient features: The right posterior thoracic margin rounded and bears a trifid process. The left side bears a triangular process. The genital segment has a long narrow spine on its left corner. The caudal setae appear to be jointed.

Remarks: This variety has been observed only in male. Five specimens of this were found in a collection from Adayar, made when the bar was open.

Labidocera kroyeri var nov?

Occurrence: Large numbers of this Labidocera have been taken in the plankton at Krusadai as well as Madras from November to December. Only females have so far been encountered.

Size: Length Female 2·5 mm.

Colour: Body has a light green colour while the caudal furca appears red.

Salient features: The form resembles L. Kroveri Brady in general shape, in the structure of the mouth parts and other appendages but differs in the ornamentations of the abdominal segments. Among the forms taken from Galexea Reef, Kundagal Channel, Adayar, and Madras plankton, considerable difference exists in the projections on the abdominal segments. These differences peculiar to each area is tabulated in the Table below:

Environmental Variations Noted in L. kroyeri

	Kundagal Channel (Fig. 13)	Galaxea Reef (Fig. 14)	Adayar plankton (Fig. 16)	Madras plankton (Fig. 18)
Number examined ..	5	4	10	10
Genital segment ..	The right side of the genital segment bears two rounded processes while the left side is produced into a bifid process.	Not produced on the right side.	With two broad spinuous projections on the right side.	Produced into acute process on its right side.
Anal segment ..	The anal segment bears a bifid process towards the outer side and a trifid process about the middle.	A trifid process towards the outer side and a bifid process on the inner side (Fig. 15).	Produced on the right side into an outer short and an inner long process while the margin bears a single trifid process about the middle (Fig. 17).	Right posterior with a short blunt process, a long bifid process and a trifid process about its middle (Fig. 19).
Furcal ramus ..	Slightly asymmetrical.	Slightly asymmetrical, caudal setae jointed.	Caudal furca symmetrical	

Labidocera bengalensis, Krishnaswamy.

(Krishnaswamy, 1952, P. 321. Text Fig. 12, 15)

Occurrence: In the plankton this Labidocera appears in large numbers from July to December.

Size: Length Female 1·4 mm. Male 1·18 mm.

Colour: The male as well as the female is of a dirty yellow colour. The abdomen is reddish in colour. Red pigment spots are scattered about on the cephalothorax. (This species can be easily identified by the squared anterior part of cephalosome, by the prolongation on the left side in the male and by the presence of tubercles and the structure of the fifth leg in the female).

Labidocera minuta Giesbrecht.

(Wolfenden 1905, P. 1018-19. Pl. XCVIII. Figs. 18, 24, 25, 29, 32 and 37).

Occurrence: This is the first record of the occurrence of this copepod at Madras. It occurs in the Madras plankton from July to February and in Krusadai plankton from February to April.

Distribution: This copepod has been recorded from Hongkong, the Great Barrier Reefs, the Malay Archipelago, South Burma Coast, Nicobar Islands, the Ceylon Pearl Banks, the Lacadives and Maldives, the Arabian Sea, the Persian Gulf, the Red Sea, and the Suez Canal.

Size: Female 2 mm. Male 1·5 mm.

Colour: Of a dirty brownish colour with bands of dark brown on the cephalothorax.

Salient features: Lateral hooks small. The last thoracic segment produced on the right side and armed with a spine. The left not produced. Abdomen three jointed in the female. Genital segment long. Anal segment very short. Furcal ramii a little asymmetrical. There is a lateral swelling and out-growth on the left side as well as above the genital opening. In the female last thoracic segment is produced into a narrow process on the right side. Antennule 17-jointed.

Remarks: A nematode is often inside this copepod.

Labidocera detruncata (Dana).

(Giesbrecht 1892, P. 445. Pl. XXIII. Figs. 14, 34, Pl. XXV. Fig. 28, Pl. 4xli. Figs. 9, 30).

(Wolfenden 1906, p. 1017-1018. Pl. XCVIII. Figs. 16, 19, 21, 34, 36).
(Sewell 1949, P. 249).

Occurrence: This is the first record of the occurrence of this copepod at Madras. Three females and a single male were found in the plankton collected on 31-1-1948.

Size: Length 2·2 mm.

Colour: Formalin preserved specimens of a dirty yellow colour.

Distribution: The Pacific Ocean, South China Sea, the Bay of Bengal, Nicobar Islands, Ceylon Pearl Banks, the Lacadives and Maldives, the Arabian Sea, the Durban Bay.

Salient features: Cephalic hooks absent. The posterior margins of cephalothorax produced into two small processes. Genital segment very large. A number of tubercles are found projecting from the genital segment which has a swelling dorsally. The furcal segments, which are uniform are asymmetrically arranged.

Remarks: The specimens from Madras closely agree with the figures given by Wolfenden (1906). Wolfenden considers his specimens to be a variety of *Labidocera detruncata*. On the other hand Sewell (1947) treats it as a full fledged species and the same is adopted here.

Labidocera pectinata (Thompson & Scott).

(Thompson & Scott, 1903, p. 252, pl. ii. Fig. 10-14).

Occurrence: This is the first record of the occurrence of this copepod at Madras. This copepod was originally described by Thompson and Scott from the Ceylon Pearl Banks in 1905 and later from the Gulf of Mannar and Bay of Bengal by Sewell.

Size: Length Female 2·0 mm.

Colour: The body of brown colour with darker bands on the Cephalothorax and red spots scattered elsewhere.

Salient features:: Cephalothorax dilated in the middle and slightly tapering towards each end. Posterior corners produced into acute lobes. The genital segment bears two curved protuberances on its right side and the last joint bears on its right side a small projection. Caudal furca is also slightly asymmetrical.

Remarks: This copepod occurs at Madras as well as Krusadai from November to March. It appears to be confined to Indian waters, as it has not been recorded elsewhere.

Genus Pontella Dana.

Pontella danae var ceylonica Thompson & Scott.

(Thompson & Scott, 1903 p. 252-253, pl. II. Figs. 1 to 5).

Occurrence: This copepod occurs from October to May in Madras as well as Krusadai plankton.

Distribution: This variety appears to be confined to the Eastern Shores of India, and is known to occur in Ceylon Pearl Banks, Madras, Gulf of Mannar, Bay of Bengal.

Size: Female 3·2 mm.

Colour: Bright green. Eyes violet in colour.

Salient features: Lateral hooks present. The posterior corners of cephalothorax produced acutely. Abdomen is asymmetrical and composed of two segments, which are indistinctly fused. Caudal furca asymmetrical, the left ramus being longer than the right one. The fifth leg is asymmetrical in female, the left exopod being longer than the right one with bifid tips. This variation is found in the female only.

Pontella andersonii Sewell.

(Sewell, 1912, p. 344-346. pl. xx. Figs. 1 to 9).

Occurrence: This copepod is being recorded from Madras for the first time. This was described by Sewell from the specimens taken on the Burma Coast. Several immature females were taken in July and September at Madras.

Size: 3·34 mm.

Colour: Preserved specimens coloured yellow.

Salient features: Anterior end of cephalosome rounded. Rostrum bifid. Posterior corners of the last thoracic segment terminates in a sharp lateral spine. Side hooks present. Abdomen two jointed. Purca symmetrical. Fifth leg with a single jointed exopodite and endopodite.

Remarks: The forms that were taken here so far agree with stage 3, described by Sewell.

Pontella securifer Brady.

(Brady 1883, p. 96, pl. 45).

Occurrence: Several males of this have been taken from October to May but not in large numbers. Considerable numbers of this were present in the plankton collected off Pulli Islands in 1937.

Colour: The formalin fixed specimens appear to be of a light red colour.

Distribution: Widely distributed in all the great oceans of the world.

Size: 3·8 mm.

Salient features: Base of rostrum swollen into a conspicuous sphere by two rostral lenses. Rostrum pointed. The cephalic hooks are prominent. Abdomen is composed of five joints. The fifth leg well developed and prehensile.

Genus: *Pontellopsis* Brady.

Pontellopsis herdmani Thompson & Scott (Fig. 48).

(Thompson & Scott 1903, p. 253. pl. 11. Figs. 15 to 17).

Occurrence: This species is being recorded for the first time at Madras. This is never very common in Madras or at Krusadai. Several specimens (all females) have been taken in December, January, August and October.

Size: Female 2·0 mm.

Colouration: This copepod is brilliantly coloured. The mid-dorsal portion of the cephalothorax is orange coloured with sides of light yellow. Abdomen yellowish dark chocolate coloured spots are scattered on the dorsal side.

Salient features: The anterior end of cephalothorax tapered and the posterior margins drawn out into acute processes. Abdomen three jointed of which the first bears a number of unmistakable spinules and ridges and has its right posterior corner drawn out into a spinous process. The fifth leg consists of two curved, slender, unjointed processes, which are bifid at the tip.

Remarks: Very often algae are found growing on the cephalothorax and abdomen of this species.

Pontellopsis villossa Brady.

(Brady, 1883, p. 86, pl. xxxv. Fig. 14-20 & Pl. XXXIV Fig. 10 to 13).

Occurrence: This is the first record of the occurrence of this copepod in Indian waters. A single female was present in the plankton from Madras dated 31-1-1949.

Distribution: Previously this copepod is known from Atlantic, Pacific Ocean. Red Sea, Gulf of Guinea, Malay Archipelago.

Size: 3 mm.

Colour: Of a light blue colour. The colour is light towards the middle of cephalothorax.

Salient features: Posterior corners of cephalothorax produced into acute processes. Lateral hooks absent. Antennule short reaching 3/4 of the cephalothorax. The second joint of abdomen is produced on the left side at the distal extremity into a cushion-like protuberance with a few spines at the apex. Abdomen hirsute. (Fig. 12).

Remarks: This copepod can be at once recognised by the peculiar protuberance of the abdomen.

Genus: *Calanopia* Dana.
Calanopia elliptica (Dana).
(Brady, Challenger Reports Vol. VIII, p. 85, pl. XXXIV. Figs. 1-9, 1888).

Occurrence: This copepod, which appears to be confined to the tropical Pacific and Indian Oceans, occurs in November and December in Madras plankton and in September at Krusadai.

Distribution: The Pacific Ocean, the Great Barrier Reefs Malay Archipelago, South Burma, Nicobar Islands and the Bay of Bengal, the Arabian Sea, the Red Sea, the Suez Canal and the Mediterranean Sea.

Size: Length Female 1·9 mm. Male 1·6 mm.

Colouration: The cephalothorax is of a light green colour with red and dark brown patches. Eye is of a violet colour and abdomen is light green.

Salient features: The cephalothorax is nearly two and a half times as long as the abdomen and caudal furca, and is elliptical in shape. The fifth legs are asymmetrical in the female, the left one being longer than the right one.

Calanopia aurivilli Cleve.
(Scott, 1909, p. 181. pl. XLVIII. Figs. 16-20).

Occurrence: This is the most common Calanopia of the Madras area occurring in the plankton from September to January at Madras and till April in Krusadai plankton.

Distribution: This has a wide distribution in Indian waters and has been recorded from Malay Archipelago, Ceylon Pearl

Banks, Gulf of Mannar, Bay of Bengal. This is the first record of its occurrence at Madras.

Size: Length Female 1·3 mm. Male 1·1 mm.

Colouration: The Cephalothorax is of a dark red colour with yellow patches. The abdomen is light yellow, eye violetish red.

Salient features: The cephalothorax is nearly one and a half times as long as the abdomen and has acute posterior corners. The genital segment is broader than long in the male and is shorter than the succeeding segment. In the male the caudal furca diverge at an angle of about 45°.

Calanopia thompsonii A. Scott.

(Scott, A., p. 178, pl. XLIX. Figs. 1-18, 1909).

Occurrence: This is the first record of the occurrence of this copepod at Madras and this occurs at Krusadai in October and in December at Madras.

Distribution: This is known to occur in the Malay Archipelago, Gulf of Mannar and the Bay of Bengal.

Size: Female 2·4 mm. Male 2·0 mm.

Colouration: The cephalothorax is of a dirty yellow colour with dark brown patches.

Salient features: The animal is slender and long. The cephalothorax is provided with lateral hooks. Abdomen three jointed in the female and four jointed in the male.

Remarks: The copepodites of this form have been described and figured by Sewell (1932) in detail.

Family: ACARTIIDAE.
Genus: *Acartia* Dana.
Sub-genus: *Odantacartia* Steuer.
Acartia (*Odantacartia*) *erythraea*. Giesbrecht.

(Giesbrecht, 1892, P. 523, Pl. 30 and 43).

Occurrence: This is one of the stationery copepods in the area under investigation that is present throughout the year.

Distribution: It has been recorded from the Malay Archipelago, Nicobar Islands, Madras, the Ceylon Pearl Banks, Travancore Coast, Indian Ocean, Lacadives and Maldives, the Arabian Sea, the Red Sea, and the Durban Bay.

Size: Female 1·2 mm. Male 1 mm.

Colour: Colourless and transparent. Eye red in colour.

Salient features: Body long and slender. The posterior corners of cephalothorax bear a spine each. Fifth leg in female consists of a single claw like spine. In the male the second abdominal segment has lateral expansions and carries a number of short spines.

Remarks: This appears to breed in February and March. An Isopod parasite, *M. Acartii* Gnanamuthu and Krishnaswamy (1948) is commonly found in this.

Family: TORTANIDAE.
Genus: *Tortanus* Giesbrecht.
Sub-genus: *Tortanus* Sewell.
Tortanus (*Tortanus*) gracilis (Brady). (Fig. 21).
(Brady, 1883, p. 71. Pl. XXXIII. Figs. 1-14).

Occurrence: This is one of the commonest copepods in Madras as well as Krusadai plankton, reaching its maximum concentration in September and December.

Distribution: It has been recorded from the Pacific Ocean, Red Sea, Malay Archipelago, Arabian Sea, Maldives and Lacadives, Bay of Bengal, Gulf of Mannar.

Size: Female 1·9 mm. Male 1·4 mm.

Colour: The cephalothorax is marked with alternating bands of dark brown or yellow. The basal portions of mouth parts are all deep yellow in colour caudal furca deep yellow or brown.

Salient features: The anterior end of cephalothorax more or less squared with a slight projection in the middle. The posterior corners bear two rounded projections. Caudal furca slightly asymmetrical. In the female the fifth leg consists of two long slender awl-shaped processes with their outer margins carrying three teeth (Fig. 22). In the male the right antennule is geniculate.

Tortanus (Tortanus) forcipatus (Giesbrecht).
(Sewell, 1914, P. 249. Pl. XXI, Fig. 6).

Occurrence: This copepod is being recorded for the first time from Madras. Several males and females were found in the plankton collected in July in Madras and from October to March in Krusadai.

Distribution: The Red Sea, Malay Archipelago, Ceylon Pearl Banks, Maldives and Lacadives, Gulf of Mannar.

Size: Female 1·2 mm. Male 1·0 mm.

Colour: Body of a bright yellow colour with alternating bands and dark brown. Caudal furca of bright yellow or brown colour.

Salient features: Anterior end of cephalosome with a small projection. The posterior corners of cephalothorax with two knob-like projections. Caudal furca asymmetrical. Fifth leg asymmetrical in female, the left one twice as long as the right. (Fig. 24). The right antennule of male geniculate.

Remarks: Cleve (1903) and Wolfenden (1905) doubt the distinction between *T. gracilis* Brady and *T. Forcipatus* Giesbrecht. *T. forcipatus* is distinguished from *T. gracilis* by the left fifth leg being asymmetrical in the former. As pointed out by Cleve, the left leg in *T. gracilis* is not quite symmetrical, but in *T. forcipatus* the left leg is twice as long as the right and the present author who had an opportunity to examine both *T. forcipatus* and *T. gracilis* feels that the asymmetry in the former is "too great to justify any doubt regarding the distinctness of the two forms." (Scott, 1909).

EXPLANATION TO TEXT-FIGURES 1 to 24

Fig. 1 *Undinula vulgaris* var *giesbrechti*.
Fig. 2 *Undinula vulgaris* var *giesbrechti*.
Fig. 3 *Centropages calaninas*, 5th leg.
Fig. 4 *Pseudodiaptomous aurivilli*.
Fig. 5 *Schmackeria serricaudatus*.
Fig. 6 *Metacalanus aurivilli*.
Fig. 7 *Suezia Sp.* Last thoracic segment.
Fig. 8 *Suezia Sp.* 1st leg.
Fig. 9 *Suezia Sp.* 5th leg.
Fig. 10 *Candacia pachydactyla*, genital segment.
Fig. 11 *Candacia discaudata*, 5th leg.
Fig. 12 *Labidocera pavo*, furcal ramus.
Fig. 13 *Labidocera kroyeri* var nov.?, from Kundugal channel.
Fig. 14 „ „ „ nov. ?, from Galexea Reef.
Fig. 15 „ „ „ nov. ?, from Galexea Reef.
Fig. 16 „ „ „ nov. ?, from Adyar plankton.
Fig. 17 „ „ „ nov. ?, from Adyar plankton.
Fig. 18 „ „ „ nov. ?, from Madras plankton.
Fig. 19 „ „ „ nov. ?, from Madras plankton.
Fig. 20 *Pontellopsis villosa*.
Fig. 21 *Tortanus (Tortanus) gracilis*
Fig. 22 *Tortnaus (Tortanus) gracilis* 5th leg.
Fig. 23 *Tortanus (Tortanus) forcipatus*.
Fig. 24 *Tortanus (Tortanus) forcipatus*. 5th leg.

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Ascomycetes from South India—II

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ABSTRACT

Two ascomycetes: *Julella sarcostemmatis* sp. nov. and *Massarina sarcostemmatis* sp. nov. on *Sarcostemma brevstigma,* are described from South India.

5. *Julella sarcostemmatis* sp. nov.

Perithecia black, minute, semi-erumpent; asci stout, broadly clavate, two-spored, 72-93 x 24-29 μ; ascospores very large, hyaline, muriform, elliptical, 42-54 x 16-19 μ; paraphyses numerous, as long as the asci, bifurcated above the middle.

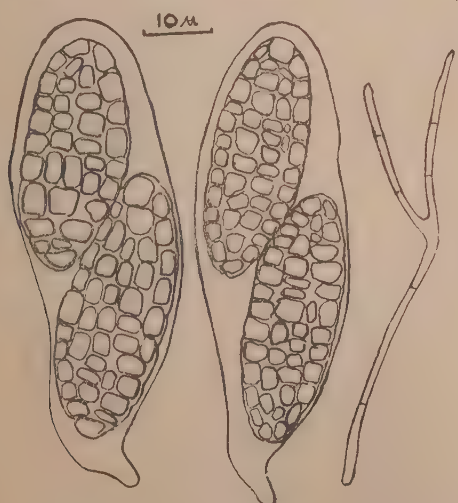

Fig. 1. *Julella sarcostemmatis,* asci and paraphyses

On living stems of *Sarcostemma brevistigma* Wt. & Arn., Christian College campus, Tambaram (Chingleput Dist.,), 5-iv-1953, coll. C. V. Subramanian, Herb. M.U.B.L. No. 892 (Type).

Perithecia atra, minuta, semi-erumpentia; asci robusti, late clavati, 2-spori, 72-93 x 24-29 μ; ascosporae amplissimae, hyalinae, muriformes, ellipticae, 42-54 x 16-19 μ; paraphyses plures, filiformes, ascis aequilongae, bifurcatae ad apicem.

In culmis viventibus *Sarcostemmatis brevistigmae* Wt. & Arn., in campo Christian College, Tambaram, Chingleput Dist., 5th Aprilis 1953; legit C. V. Subramanian; Herb. M.U.B.L. No. 892 (Typus).

The genus *Julella* was erected by Fabre (1880), for an ascomycete with 1-2 spored asci the ascospores being very large, hyaline and muriform. As far as the author is aware no species of *Julella* has been described on *Sarcostemma* or any other member of the Asclepiadaceae. Apart from this fact the

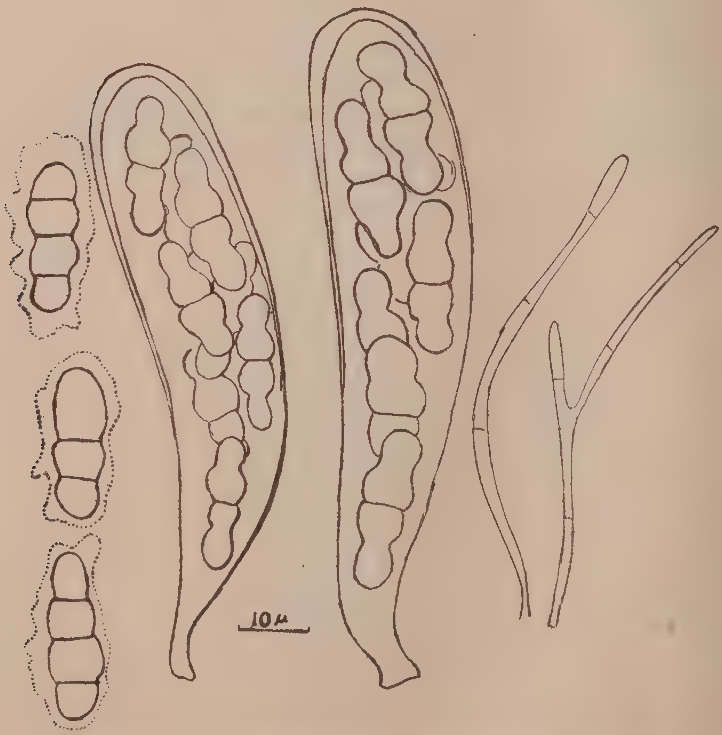

Fig. 2. *Massarina sarcostemmatis,* asci, ascospores and paraphyses.

present fungus differs in ascus and ascospore measurements from all the five species of this genus described so far. It is, therefore, considered necessary to describe it as a new species.

6. *Massarina sarcostemmatis* sp. nov.

Perithecia minute, black, semi-erumpent; asci clavate, bitunicate, 8-spored, 88-112 x 21-26 μ; ascospores hyaline, 3-septate, deeply constricted at the septa, 24-29 x 8-11 μ, surrounded by a mucilaginous envelope about 4 μ in thickness; paraphyses numerous, filamentous, bifurcate at the apex or unbranched.

On living stems of *Sarcostemma brevistigma* Wt. & Arn., Christian College campus, Tambaram, (Chingleput Dist.) 5-iv-1953, coll. C. V. Subramanian, Herb. M.U.B.L. No. 891 (Type).

Perithecia minuta, atra, singula, bina vel terna, semi-erumpentia; asci clavati, bitunicati, 8-spori, 88-112 x 21-26 μ; ascosporae hyalinae, 3-septatae, altae constrictae ad septum, 24-29 x 8-11 μ, circumdatae involucro mucilaginoso ca. 4 μ crasso; paraphyses plures, filiformes, bifurcatae ad apicem.

In culmis viventibus *Sarcostemmatis brevistigmae* Wt. & Arn., in campo Christian College, Tambaram, Chingleput Dist., 5 aprilis 1953, legit C. V. Subramanian, Herb. M.U.B.L. No. 891 (Typus).

From a study of the literature it appears that the 35 species of the genus *Massarina* so far described have been delimited on the basis of the host, even when the fungi occupied dead material. Following this trend the present fungus is considered new as there is no record of a *Massarina* on *Sarcostemma.*

The dehiscence of the bitunicate ascus in this fungus is similar to that reported by the author (Ramakrishnan, 1953) for *Polyclypeolum salvadorae.*

I am deeply grateful to Prof. T. S. Sadasivan, who went through the manuscript critically and to Rev. Fr. H. Santapau of the St. Xavier's College, Bombay, who translated the diagnoses into Latin.

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Hydrobiological Studies in the Madras Coastal Waters

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ABSTRACT

A review of the work on hydrology and plankton in Indian waters is made and a brief reference to the methods of collection and measurement of plankton and to the methods of analysis of the different constituents of sea water is given.

Measurements of temperature, salinity, pH, dissolved oxygen, phosphates, nitrites and silicates in the surface waters of the Madras coast are made during the period February '51 to April '52 and the salient features in their seasonal distribution based on monthly average values are given. Observations on the fluctuations of phytoplankton and zooplankton from the surface tow-net collections are made during the same period. The possible relationships between the diatoms and the available physico-chemical factors are discussed. The occurrence of the zooplankton and its main components is considered in relation to certain of the hydrographical factors and also in relation to the diatoms.

A programme of study of the vertical distribution of physico-chemical conditions and plankton in the Madras coast is given and the results of determinations of transparency, temperature, salinity, pH, dissolved oxygen, phosphates, nitrites and silicates made during the visits for the period Sept, 1952 to April 1953 are tabulated.

Introduction

Our knowledge of the hydrobiology of the Indian coastal waters is very meagre especially the relation between the plankton and the physico-chemical factors. Most of the plankton investigations in Indian coastal waters have been on the systematics and on the seasonal occurrence of the different planktonts. However, a few investigators have attempted to correlate their results with the physical conditions of the sea (Hornell & Nayudu 1923; John 1937; Chidambaram and Menon 1945; Jacob and Menon 1947; Chacko 1950; and George 1952), while others have studied the physical

and or chemical conditions alone (Bal et al 1946; Jayaraman 1951; and Seshappa 1953a & b). Contributions towards the knowledge of Indian hydrography by Sewell (1929), Thompson and Gilson (1937) and Raghuprasad (1952) deal chiefly with the conditions in the open sea. The first account of physico-chemical conditions in the subsurface levels of an inshore area is contained in a paper by Chidambaram et al (1951) whose records deal with conditions noticed in a month. Similarly observations by Chidambaram and Rajendran (1952) on the hydrology of Wadges Bank refer to physical conditions at surface and subsurface levels noticed in a month. Thus a review of the available literature will indicate the paucity of bio-hydrographical data of intensive nature, for the surface waters and more particularly for subsurface waters in the Indian coast. Hence a study of the plankton of the Madras coast in relation to some of the hydrographical factors was considered worth attempting.

In the present paper are presented

(1) methods and results of analyses of plankton and sea water samples taken from the surface waters during February 1951 to April 1952 and

(2) programme of study of vertical distribution of plankton and physico-chemical conditions begun eight months ago.

PART I*

Material and Methods

Plankton samples (numbering 135) were collected at the surface during Feb. '51 to April '52 by horizontal hauls using the ordinary tow-net of mercerised linen having 400 meshes/sq. cm. and a catamaran (country craft). Three hauls of definite duration were made. The area of collection was a shallow inshore one of a depth of about 8 fms and the observations were restricted to a single station throughout. Pigment content of an aliquot portion of the fresh plankton was determined and expressed as Harvey's pigment units. The remaining portion of the plankton was preserved. The volume of the plankton caught was measured by displacement method. The numbers of total diatoms and the different

* Formed part of the thesis approved for the M.Sc. Degree of the University of Madras.

groups of zooplankton organisms were counted in a fraction of the catch diluted to a suitable concentration. Several subsamples were counted so as to ensure a fair degree of accuracy. Further accuracy in quantitative studies can be secured by power driven craft and equipments for the measurement of currents.

Temperature of surface water was recorded by means of a centrigrade thermometer. (Reversing thermometer being used for deeper layers of the sea-vide infra). Sea water samples were brought to the laboratory from the site of collection in coloured bottles and analysed within 2 or 3 hours after collection. Salinity and pH determinations were made on 123 water samples of which 55 were also analysed for dissolved oxygen, inorganic phosphates, nitrites and silicates. Salinity was determined by Mohr's method of the titration of chlorides using silver nitrate. Standard sea water supplied from Copenhagen was used for reference. Hydrogen-ion concentration was estimated on the Hellige's comparator using cresol red as indicator, the values being corrected for salt error. Dissolved oxygen was determined by Winkler's titration method. Phosphates were determined by ceruleo-molybdate method of Deniges as applied to sea water by Atkins (1923), following the modifications in the volume of reagents added, as adopted by Cooper (1938) to minimise the salt error. Colour comparisons were made usually in Hehner cylinders and the values not corrected for salt error, were expressed as mgP_2O_5/L. Nitrites were estimated by means of Greiss-Illosvay reagents as followed by Orr (1926). The reagents and standard solutions were renewed often. Colours were compared in Hehner cylinders. Silicates were estimated by the colorimetric method of Dienert and Wandenbulcke as modified by Atkins (1926). The fluctuations in the plankton and physico-chemical condition are discussed in terms of monthly averages. The data are presented here in two sections. Section A dealing with the physical and chemical features of the surface waters and Section B dealing with the biological features of the plankton.

Section A: *Physical and chemical features of the surface waters* (Table I).

Temperature ranged from 27·16° to 30·1°C. It was low during November-January which coincided with the North East monsoon. Salinity showed a range from 26·23 o/oo to 34·94 o/oo. Marked dilution was observed in November which was due to influx of river water consequent of the outbreak of the monsoon.

Table I showing the mean monthly records of the physico-chemical conditions at the surface during February 1951 to April 1952

Months	Temp. °C	Salinity o/oo	pH	Dissolved oxygen ml/L	P_2O_5 mg/L	NO_2 N mg/L	Si mg/L
February ..	27·3	30·63	8·16	4·055	0·0238	0·001	0·27
March ..	28·6	34·52	8·10	3·925	0·046	0·002	0·308
April ..	29·3	34·94	8·17	3·920	0·03	0·0008	0·29
May ..	29·2	34·68	8·20	3·940	0·085	0·0032	0·4
June ..	28·0	34·32	8·15	4·105	0·046	0·0018	0·24
July ..	28·3	34·44	8·00	4·018	0·0245	0·0041	0·373
August ..	28·0	34·12	8·02	3·940	0·0468	0·00375	0·348
September ..	29·4	33·53	8·02	3·936	0·0326	0·0028	0·316
October ..	30·1	32·39	8·05	3·815	0·0378	0·00173	0·405
November ..	28·5	26·24	8·11	4·03	0·0655	0·0026	0·588
December ..	27·4	28·80	8·12	4·293	0·045	0·0019	0·67
January ..	27·16	30·06	8·07	4·373	0·0503	0·0008	0·47
February ..	27·8	30·73	8·17	4·183	0·0327	0·00057	0·31
March ..	28·48	33·69	8·18	3·947	0·0268	0·0019	0·285
April ..	30·07	33·84	8·24	3·955	0·026	0·00025	0·23

pH and dissolved oxygen showed very little seasonal change ranging from 8·00 to 8·24 and 3·815 ml/L to 4.375 ml/L respectively. The former showed no relation to either temperature or salinity changes. The oxygen content was very low compared to temperate waters. Maximum values for dissolved oxygen were observed during November-January when the temperature and salinity were low. Phosphates ranged between 0·024 mg/L - 0·085 mg/L. They never reached even near to the point of complete exhaustion. They were always available in appreciable amounts. Nitrites No_2N ranged from 0·0002 mg/L to 0·0041 mg/L. They showed either total or marked depletion on several occasions unlike phosphates. Silicates (Si) ranged from 0·23 mg/L to 0·67 mg/L and their general distribution was similar to that of phosphates. Markedly high values were noticed in November and December when the salinity was low. It is probable that the silica content owes its high values to the fresh waters mixing with sea water.

Section B: *Biological features of the surface plankton* (Figs. 1, 2 & 3).

The mean monthly values for the volume of the plankton catch varied only to a small extent during the different seasons of the year, the highest value being only 2·5 times as large as the lowest value (10 c.c.).

Phytoplankton: Throughout the period diatoms were numerically the most important photosynthetic organisms. The blue-green algae, *Trichodesmium sp.* occurred sporadically and swarms of these algae were noticed in February. Dinoflagellates were by far less numerous than the diatoms and their variations mostly followed those of the diatoms. The pigment extraction method was found to be useful in indicating the general trend of diatom production, especially when analysing a number of plankton samples. The distribution of the diatoms was quite irregular, a feature being very high productivity in the months of February, April, May, August, September, November and December and low production in January, March, June, July and October.

Zooplankton: The total zooplankton was found to be rising from December till May. The pronounced peaks observed in May and again in August were chiefly due to swarms of *Noctiluca Sp.* The larvae of the invertebrates occurred throughout the year. Polychaete larvae were abundant in April and August. Molluscan larvae occurred abundantly in July. Copepod nauplii showed two maximal occurrence, the first being in May and the second in

August. In November and December their numbers were again on the increase. Decapod larvae were abundant in March-July. Cirripede larvae and cyphonautes appeared irregularly. Plutei occurred abundantly in October and November. Cladocerans

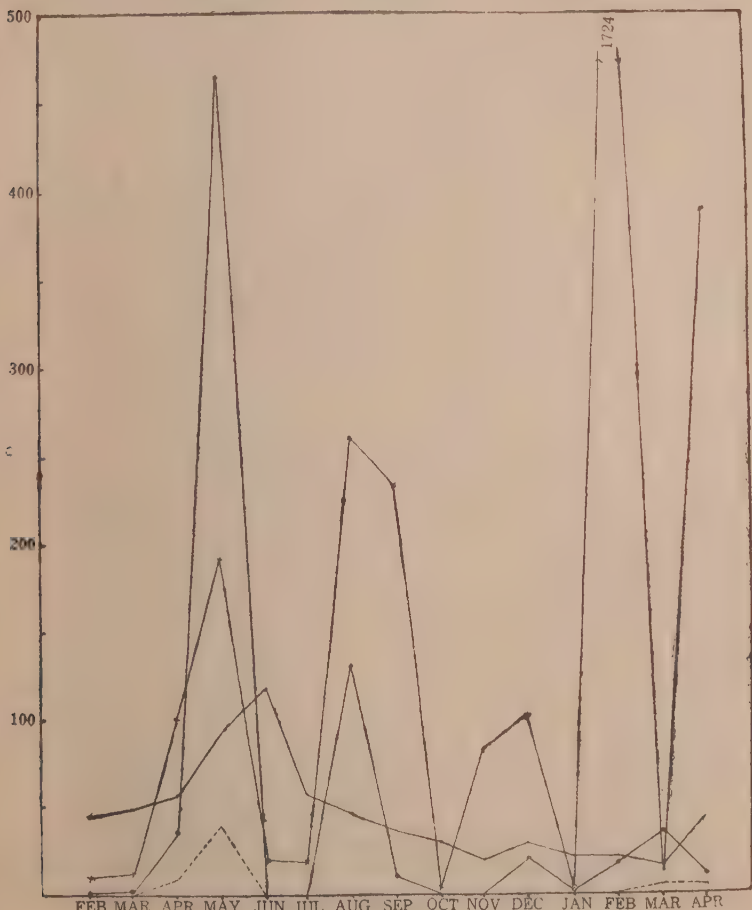

Fig. 1. Seasonal Variations in diatoms, Noctiluca, copepods and cladocerans.

Diatoms in lacs
Noctiluca
Copepods
Cladocerans
} in thousands

appeared in significant numbers only in April and May. The copepod abundance was found to be during April-July. Maximal

numbers of chaetognaths were obtained from May-July, with a secondary maximum in November-December. There were two periods of maxima in the occurrence of salps. The first period

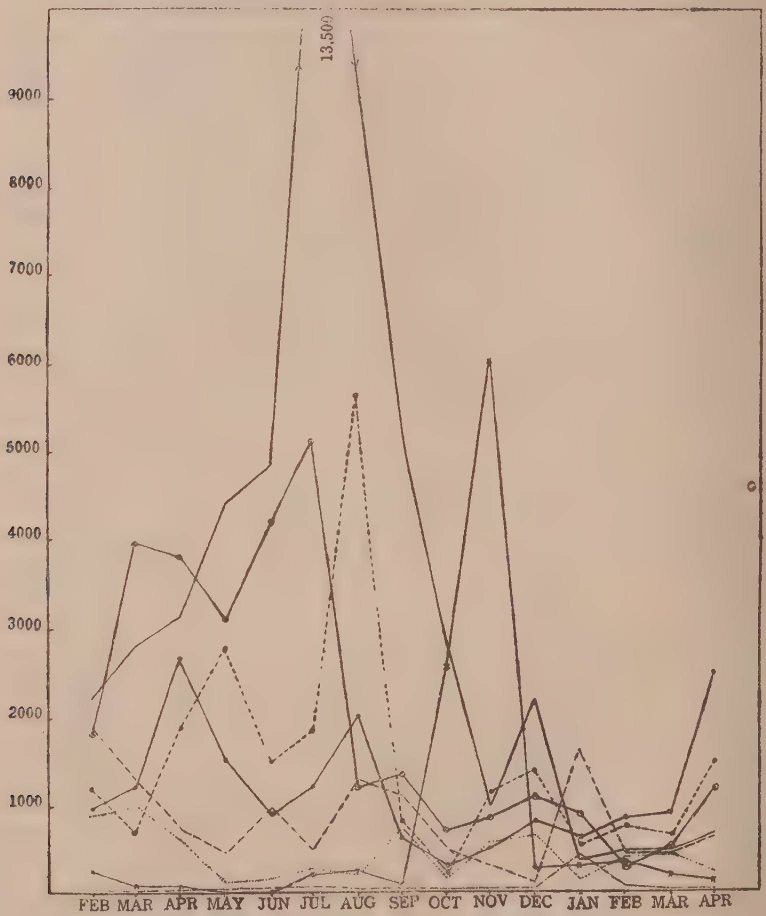

Fig. 2. Seasonal Variations in planktonic larvae.

Molluscan larvae
Plutei
Cirripede larvae
Cyphonautes
Decapod larvae
Copepod nouplii
Polychaete larvae
Fish eggs

extended from January to March and the second period of less importance included August. Fish eggs appeared in considerable

numbers in February & July but their maximum numerical intensity was in January.

Discussion: In general, the seasonal variations of diatoms in Madras were not so well pronounced as in temperate regions. Instead of being restricted to few months of vigorous production (spring and autumn diatom outbursts) as in temperate waters, with the return of sunshine following nutrient replenishment over the winter, it is clear that, here, production was more or less spread throughout, interrupted by one or two months of sparse diatom populations. Both salinity and temperature did not appear to be causally associated with any changes in phytoplankton growth. pH, though it did not closely follow changes in phytoplankton, increased in the months when the diatom peaks occurred. It was independent of changes in oxygen content. The latter was never very far from saturated and was mainly influenced by water temperature rather than by photosynthetic activity (Murthy 1953). Coincident with the absence of a marked seasonal growth in diatoms in the Madras coastal waters, the seasonal cycle in the phosphate content was not well marked. The minimum average value noticed here was 0·024 mg/L. This is suggestive, that the surface water, here, is at its poorest, nearly as rich in phosphates, as the English channel, at its richest, where the reported values range between 40-75 mg Po_4/L, just prior to the spring outburst, While the phosphates were never reduced to zero, nitrites went down to zero or to a mere trace on certain days which coincided with dense diatom growths. Although such reductions were variations of importance, they were only of short duration, since this condition did not last for any considerable period. Previous studies in the Madras coastal waters (Jayaraman 1951) showed that nitrate changes closely followed nitrite changes. Hence it may seem that the nitrogen content is more sensitive to phytoplankton production than the phosphates, although it is unlikely that it affects seriously phytoplankton production in Madras.

Since the nutrients (phosphates, nitrites & silicates) were always found to be available and since there is in the tropics a uniform amount of sunshine, one would expect the production of phytoplankton to be uniform. However the amount of phytoplankton was below average during January, March, June, July and October and it is to be explained by other factors like rapid removal by currents, grazing off by zooplankton and senescence of diatoms.

It was observed that the lowest ebb of the zooplankton especially the copepods occurred in November when the salinity was lowest. At first sight, this would appear to support Sewell (1913), who suggested that in the Bay of Bengal, the great changes in salinity might probably influence the distribution of copepods. But the fall in salinity in November was sudden while the fall in the population commenced even in July and happened to reach minimal numbers in November, so that salinity alone did not seem to

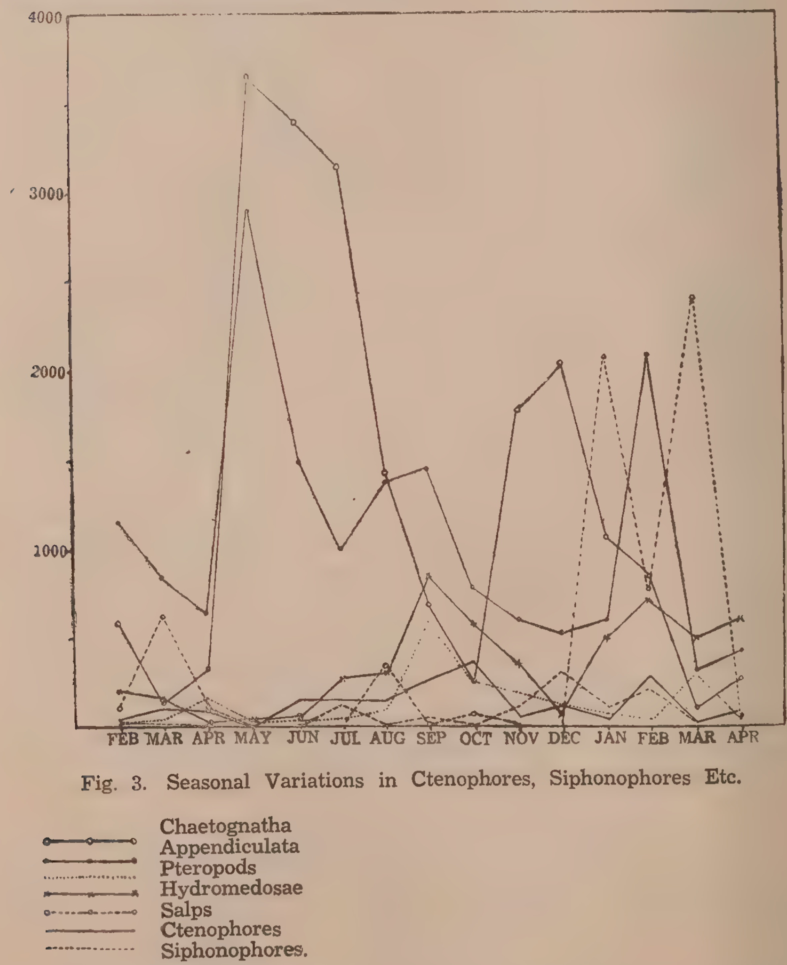

Fig. 3. Seasonal Variations in Ctenophores, Siphonophores Etc.

be the sole factor responsible for the scarcity in copepod population. While only experimental tests would prove conclusively whether or how far the pelagic copepods would tolerate differences

in salinity, it will be in the fitness of things to seek explanation for the decline in the copepod population observed till November, in factors such as the water movements and inshore migration of plankton feeders.

The periodical appearance of salps along the Madras coast seems to be greatly influenced by salinity, temperature and currents as was observed by Nair (1949). The seasonal distribution of the chaetognaths is not related to salinity or temperature changes. The period of maximal abundance of *Sagitta* during May-July coincided with the abundance of copepods and other microcrustaceans. It remains to be investigated how far the abundance of *Sagitta*, during certain seasons, may depend on the abundance of certain other planktonic organisms which constitute their food and also on the water movements in the Bay. The occurrence of forms like hydromedusae, siphonophores and ctenophores in the plankton is suggestive of currents and strong winds conveying them into the inshore area.

The continual occurrence of most of the planktonic larvae of the invertebrates suggested that, to some extent, breeding takes place throughout the year. However, in certain months, it was more intensified, as indicated by increase in the larval population, which coincided mostly with the period of diatom abundance or followed the period of diatom outbreak. So it is probable that the intensity of breeding was regulated by the amount of available food. Apart from this, it is probable, that the occurrence of these larvae was related to the reproductive cycle of the adults. In the case of plutei larvae which were found to abound in October and reach the maximum numbers in November when salinity was swinging to the minimum, it is probable that the lowering of the salinity stimulated breeding in echinoderms. The abundance of fish eggs in January immediately succeeding the outbreak of the monsoon suggested that changes in salinity brought about by the rains, during the monsoon, acted as a stimulus to breeding in marine fishes as already stated by Nair (1952). However, the possibility of the occurrence of fish eggs in abundance in January being related to the reproductive rhythm in fishes has to be mentioned, in the absence of information as to the reproductive phases in the different fishes.

The zooplankton occurred in abundance about the same time or just after that of the diatoms. The sudden fall in the diatom population in June coincided with the copepod maximum, which

was probably due to the grazing effect of these herbivores in large numbers. Most of the planktonic larvae were abundant during June-July and it is extremely probable that they too would have played a part in the regulation of diatom population in those months. The peaks in the copepod nauplii, noticed to occur in the months of April-May, August and November-December coincided with the diatom peaks. Similarly other invertebrate planktonic larvae appeared in abundance either accompanying or following the diatom peaks. While the decrease in the diatom population in January and March may be accounted for by the swarms of salps which are said to be predominantly herbivorous and that in June and July may be due to grazing off by copepods and planktonic larvae, the sparse diatom population noticed in October was inexplicable. Presumably it may be in response to certain disturbed conditions in water or to physiological senescence resulting in the dying down of the population following sustained production in August and September.

It is necessary to make a comparison of the present findings in regard to plankton distribution with the previous results of Menon (1931) from the Madras coast and also with the results obtained by Menon (1945) from the Trivandrum coast. Menon (1931) recorded a general maximum for the diatom populations in April and May which was the culmination of a regular and constant diatom increase beginning in September, so that the production of diatoms was spread out. In temperate waters, on the other hand, it is the culmination of a sudden rise beginning in March. He (1931) observed that the variations exhibited by most of the planktonic organisms were not so clear cut as in more northern latitudes. The only difference noticed in the present observations appears to be that while August and September were the months of scarce diatom population in Menon's records, they are not observed to be so in the present results. However, it may be stated here, that the general features of distribution of diatoms, in so far as their production is spread out, hold good now also. The parallel variations between the diatoms and dinoflagellates were already observed by Menon (1931).

Menon's (1931) records shows that the zooplankton was abundant from October to March. In the present observations, it was found to be rising from December till May, while it was declining from June until November, except for the rise in August due to swarms of *Noctiluca*.

Menon (1945) observed a general maximum for diatoms in the Trivandrum coast, from February to September which was in general agreement with the seasonal occurrence of diatoms off Calicut (Hornell & Nayudu 1923). He (1945) noticed a regular succession of maxima in the order of Diatoms-Dinoflagellates-Copepods.

The deviations or departures noticed in the present observations from those of Menon (1931) with respect to the seasonal occurrence of the different planktonic constituents in the Madras coastal waters, are in conformity with the observations of Sears and Clarke (1940) who stated that the seasonal cycle either in the abundance or in the character of plankton is not constant from year to year.

PART II

This section deals with the investigations that have been taken up regarding the depth distribution of both plankton and physico-chemical conditions. The observations to be considered include determinations of transparency, temperature, pH, salinity, dissolved oxygen, phosphates, nitrites and silicates from water samples collected at surface and subsurface levels. A station with a depth of about 25 metres, fixed by bearings, is visited between 8-30 A.M. and 9-30 A.M. twice in a month and another station, similarly fixed by bearings, with a depth of 60 metres is being visited whenever possible. The visits are made on board the Fisheries vessel "M.F.V. VIZIANAGARAM", hired for the purpose.

Transparency is measured by a secchi disc painted white with a diameter of 30 cms. Water samples are taken with Nansen's reversing water bottle at intervals of 10 m level and the temperature at the subsurface levels is recorded by a protected reversing thermometer attached to the bottle in a frame. Temperature readings are corrected for the difference due to temperature at which the thermometer is read by applying the Schumacher formula. However, the calibration error is not taken into account. Water samples are analysed on the day of collection and the analysis is done after the methods mentioned in the previous section, except for pH which is estimated by the Glass electrode method and for colour comparisons in phosphate analysis which are done on a Unichem Photo electric colorimeter. Plankton is collected at depth intervals of 10 metres using the Standard horizontal closing net which is towed for ten minutes, the vessel steaming at 1¼ knots

Table II showing the depth distribution of Physico-chemical conditions

Date of visit	Depth of the station	Trans-parency	Depth	Temp. °C	Salinity o/oo	pH	Dissolved oxygen ml/L	P_2O_5 mg/L	NO_2N mg/L	Si mg/L
26— 9—52	12 fms	10 m	Surface	29·0	34·38	8·05	3·549	0·056	0·0002	0·21
			5 fms	28·19	34·38	8·05	3·445	0·04	0·0003	0·27
			10 fms	28·18	34·28	8·10	3·527	0·051	0·0002	0·33
10—10—52	,,	10 m	Surface	28·8	33·71	8·0	8·679	0·018	0·006	0·37
			5 fms	28·4	33·71	8·07	3·582	0·028	0·008	0·42
			10 fms	28·49	33·50	8·05	3·664	0·028	0·008	0·46
28—11—52	,,	12 m	Surface	27·0	25·69	8·29	3·808	0·041	0·0005	0·68
			5 fms	26·82	25·69	8·37	3·649	0·054	0·0006	0·71
			10 fms	26·82	26·31	8·4	3·888	0·06	0·0006	0·71
11—12—52	,,	8 m	Surface	26·9	29·13	7·8	4·017	0·06	0·0016	0·85
			5 fms	26·69	29·59	7·78	3·837	0·04	0·0016	0·73
			10 fms	26·68	29·80	7·78	3·748	0·04	0·003	0·73
18—12—52	,,	7 m	Surface	26·0	29·28	8·03	3·928	0·03	0·0028	0·79
			5 fms	26·21	29·48	8·02	3·837	0·03	0·0016	0·79
			10 fms	26·51	29·69	8·02	3·837	0·036	0·0012	0·69
5— 3—53	35 fms	22 m	Surface	28·0	32·46	8·09	4·00	0·08	0·0006	0·375
			10 fms	27·6	32·26	8·13	4·00	0·045	0·0003	0·375
			20 fms	27·7	32·06	8·17	4·293	0·028	0·0003	0·325
			30 fms	27·6	32·26	8·17	4·295	0·028	0·0003	0·350
28— 3—53	12 fms	8 m	Surface	28·0	34·13	8·10	3·971	0·03	0·0019	0·28
			5 fms	27·81	33·69	8·10	3·978	0·046	nil	0·28
			10 fms	27·81	33·69	8·09	3·972	0·03	nil	0·36
27— 4—53 (Night collection 10-30 P.M.)	12 fms	—	Surface	27·8	33·75	8·01	3·819	0·044	0·012	0·32
			5 fms	27·7	33·75	8·09	3·84	0·04	0·0008	0·32
			10 fms	27·9	33·96	8·13	3·546	0·018	0·0008	0·35

per hour. The volumetric estimations and the quantitative and qualitative analysis of the catch are carried out as mentioned in the previous section.

The transparency measured on six occasions in the 12 fm area and once in the 35 fm area during the period September 1952 to March 1953 shows a higher transparency in the latter region (22 m) than in the 12 fm area (7 m - 12 m). Summarising the results obtained so far, on the depth distribution of the physical and chemical conditions (Table II), it may be said that the vertical differences are not so great, as to indicate any stability in the water column. The plankton collections are being subject to quantitative and qualitative analysis. However, to make any conclusion or generalisation, more observations are necessary and detailed results of investigations on the biological and hydrographical conditions with a correlation analysis will be presented later, when more observations are on hand.

Acknowledgements

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Measurement of Diatom Population by Pigment Extraction Method

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ABSTRACT

Quantitative estimates of diatoms in the tow-net collections of mixed phytoplankton and zooplankton are made by Harvey's pigment extraction method and cell census method during the periods April '51—April '52 and December '52—April '53. The results obtained are compared and discussed.

Introduction

The quantity of phytoplankton present in tow-net samples is of great significance, because the plants are the primary producers of food and support the zooplankton. Further there is an intimate relationship between the plant population and the physico-chemical conditions of the sea. Hence the determination of phytoplankton present is essential in all quantitative studies of the plankton. Different types of phytoplankton measurements are frequently used. Counting the numbers in aliquot portions of the collection is not only laborious but fails to take note of the sizes of the cells. Riley (1941) investigating the plankton of the Georges Bank, made a comparative study of the various methods of plankton measurements like the cell counts, cell volume, weights of the dried plankton, organic matter and ash and finally pigment content. He calculated the correlation of the different types of measurements and showed that the chlorophyll had a higher degree of relationship with the others than any other one type of measurement. He concluded that the plant pigment content is more nearly representative of phytoplankton measurement in general than the other methods used and that the cell number is the least reliable. Aleem (1949) evolved a method of estimating the periodicity of diatom from their

silica content. He compared this method with the cell counts and concluded that the former can be used to show seasonal changes in the density of diatoms but discrepancies in the relations arise owing to the diatom size differences.

Pigment content, as a quantitative measure of diatoms was first used by Kreps and Verjbinskaya (1930). Harvey (1934, '53), Riley (1937), Gillam et al. (1939), Krey (1942), Graham (1943), Tucker (1949), Atkins & Clarke (1951) and Atkins & Jenkins (1953) used the pigment content to follow the changes in the plant crop. Harvey et al (1935) and Mare (1940) concluded that discrepancies arise in the relation between pigments and cell counts because of the size differences in the cells. However, they stated that if the cells could be weighted for size, a definite relation could be expected. Edmondson and Edmondson (1947) stressed that chlorophyll determination though it has its limitations, is of critical importance, in assessing phytoplankton production. Riley et al (1949) summarising the available data on the cell counts and the pigments, concluded that plant pigment method is the more useful one.

Although much work has been done on the seasonal variations of the diatoms in the Indian coast based on Hensen's enumeration method (Menon 1931; Menon 1945; Chacko 1950 etc.,) no information is available on the seasonal studies in the chlorophyll content of the diatoms which gives a quantitative measure of the plant population. Thompson and Gilson (1937) appear to be the only authors who have used this chlorophyll estimation of the phytoplankton of Indian waters. The object of the present study is to make a quantitative estimate of the diatoms in the different seasons of the year, using both pigment extraction method and that by cell counts and see if any relation could be found in the results obtained by these methods. This work was carried out while engaged in a study of the plankton and its relation to the hydrographical factors along the Madras coast.

Material and methods

Tow-net collections made from the surface waters of the Madras coast during the period April 1951 to April '52 and again during December '52 to April '53 form the chief basis of the present report.

Fresh plankton was used for pigment extraction. This was made by filtering aliquot portions (one fifth to one half depending

upon the concentration of the diatoms in the collections) of the catch through fine filter paper. The technique used by Atkins and Clarke (1951) to retain all the cells in the filter paper was followed. 5 ml of 10% solution of potash alum was added to every one litre of sea water to be filtered. As a result, a good floc was formed entangling the cells. It was often possible to decant off the clear liquid over the floc, thus minimising the time of filtration. The residue was then treated with a few c.c. of 80% acetone and after a few hours the acetone extract was compared with the standard colours (Harvey 1934). If necessary more acetone was added to dilute the colour so that the differences in the intensity of colours were readily seen. The results were expressed in terms of arbitrary units of pigments. The results obtained during the period April '51 to April '52 were based on visual colour comparisons and to check the feasibility of the visual measurements, colour comparisons of the extracts from the plankton collections during December '52 to April '53 were made on a Unichem photo electric colorimeter against Harvey's standard colours using a Ilford 204 Red Filter as well as visually.

For purposes of studying the relation between the cell numbers and the pigment units, the total number of diatoms in the catch was obtained from the average counts. Counts were made by individual cells in several sub samples of 0·2 c.c. and 0·5 c.c. taken from each of the three samples of the preserved catch diluted to a suitable concentration. When diatoms were teeming, further dilutions of the samples were made and counts made in the sub samples taken there-from.

In the absence of information as to the quantity of water strained, these studies involved all the errors of the tow-net method such as the uncalculated currents in the water, speed of the catamaran from which the collections were made and the degree of clogging at the meshes of the net, and the quantities of pigments stated do not have any reference to any known volume of water. In comparing the pigment units with the phytoplankton in a catch, only the diatoms were taken into account since they were obviously the most important constituents of the flora.

Results and Remarks

Table I shows the mean monthly diatom density in terms of Harvey's arbitrary pigment units and numbers of diatom cells,

computed from the analysis of the plankton catches taken during the period April '51 to April '52. Table II shows the diatom density, in terms of cell counts and pigment units estimated both by visual comparisons and by comparisons on the photo-electric colorimeter, on several days from the plankton collected during December '52 - April 1953.

It is evident that cell counts and pigment estimations were essentially in agreement, in general, as regards the seasonal distribution i.e. the fluctuations in the pigment units and numbers of cells were mostly concurrent. In the month of October, for example, the average was 16.5 pigment units and the average cell count was 1,55,590 whereas in May they were 887·5 units and 19,190,000 cells respectively. However, the cells per pigment unit and the range in cell counts, were found, from the pigment estimations and cell counts on several days, to be highly variable ranging from 400 C/U to 85,140 C/U and 8,750 to 1,527,500,000 cells (a ratio of little over than 1: 17,45,70) respectively. Plant pigments varied from 4 to 18,000 Harvey units, a ratio of 1 : 4500. These variabilities could also be seen from Table II. Hence no definite relation could be established between the total pigments and the numbers of cells. Gillam et al (1939) found that chlorophyll followed the distribution of diatoms. But the correspondence was only a broad one so that they concluded that any arbitrary colorimetric measurement based on the amount of chlorophyll present in the acetone extract could give but a very rough estimate of the diatoms present. Mare (1940) found greatest difference in the relation between pigment units and total numbers of cells in two instances. In one case, the small celled *Chaetoceros sp.* was dominant and in another the large celled *Rhizosolenia sp.* was dominant. Similarly Harvey et al (1935) stated that no exact relation would be expected between the numbers of diatoms of greatly differing sizes and the pigments in them. They, however, demonstrated that such a relation could exist if the exact size of the various diatoms was taken into consideration, with reference to the quantity of chlorophyll in them. They took into consideration the size of only three species of diatoms, whose cell contents were small, weighted them for size so that 20 cells of *Skeletonema costatum* or 3 cells of *Rhizosolenia alata* or 3½ cells of *Rhizosolenia shrubsolei* were counted as "one diatom of average cell contents" and established a clear correlation between the number of these diatoms and the quantity of pigments in them. Though no exact quantitative estimation of the different species of diatoms was attempted here, the

more dominant constituents of the flora were noted down from the plankton collections made during the period Dec. '52 to April '53. It would appear from Table II that cells/unit were high when small celled diatoms like *Chaetoceros, Asterionella* and *Bacteriastrum* were dominant and low when large celled forms like *Rhizosolenia, Biddulphia* and *Leptocylindricus* were abundant. Hence it is quite probable that a detailed qualitative study of the fluctuations in the diatoms, in which the cells are weighted for size, may lead to an understanding of the factors determining the relation between the pigment units and the cell counts.

However, the pigment units are more significant than the cell counts. It is only the chlorophyll of the diatoms that can synthesise the available inorganic nutrient salts of the sea into the organic form in significant amounts and as such figure as primary food producers. Gardiner (1943) discussed the presence of various types of pigments in the plankton algae and observed that the estimate of the algal abundance must be based on the concentration of one or more pigments common to all classes of algae. Reviewing the Harvey's method critically, he stated "the reliability of the pigment extraction method will depend to a great extent upon the constancy of the ratios of the common pigments both at different seasons and in different classes of algae."

Occasionally high pigment values were obtained as may be seen from Table II, due to the presence of abundant detritus and green organic matter in the plankton. When the diatom populations were sparse and zooplankton, particularly copepods, abundant, the acetone extract was discoloured and visual colour comparisons were made extremely difficult and consequently the pigment values were probably very rough. In such cases, colour comparisons on the photo-electric colorimeter resulted in apparently high values. As is evident from Table II, visual comparisons throughout gave values lower than the colorimetric values.

Nevertheless, from the present study, it appears that in indicating the general trend of diatom production, the pigment extraction method seems to be particularly useful, when analysing a number of plankton samples quantitatively (See Tucker 1949 and Riley et al 1949), in a study of the plankton production in relation to the environmental factors.

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TABLE I

Months	Total Cells	Pigment Units	Cells/Unit (C/U)
1951			
April (12)	7269200	333	21,830
May (4)	19190000	887·5	21,623
June (3)	1874170	150	12,495
July (11)	2545050	119	21,387
August (12)	26151330	770	33,960
September (10)	23231270	825·5	28,125
October (12)	155590	16·5	9,460
November (10)	7909675	208	38,027
December (5)	10100000	226	44,690
1952			
January (9)	623780	30	20,793
February (9)	172394820	2128	81,013
March (8)	1351740	113	11,962
April (8)	38998535	995	39,195

(Figures in brackets denote the number of cell counts and extractions made for the month and the mean is calculated therefrom).

TABLE II

Date	Total cells	Pigment units as measured on the Colorimeter	Cells per pigment unit	Pigment units as estimated by visual comparisons	Cells per pigment unit	Dominant composition of Flora
2—12—52	126000	150 (Extract discolored)	840	12	10,500	Coscinodiscus and Rhizosolenia
16—12—52	11540000	260	44,385	200	57,700	Chaetoceros and Bacteriastrum
29—12—52	4380000	80	54,750	64	68,438	Chaetoceros and Asterionella
5— 1—53	132000	80 (Extract discolored)	1,650	10	13,200	Thalassiothrix and Coscinodiscus
13— 1—53	45000000	810	55,560	540	83,333	Chaetoceros and Asterionella
23— 1—53	1776000	235 (Extract discolored)	7,557	25	71,040	Chaetoceros and Asterionella
29— 1—53	318000	572 (Extract discolored)	558	20	15,900	Chaetoceros and Thalassiothrix
2— 2—53	186000000	2880	64,580	2160	86,110	Asterionella and Chaetoceros
9— 2—53	630000	1260	500	800	788	Streptotheca (Green organic matter abundant)
17— 2—53	1650000	400	4,125	210	7,857	Chaetoceros Rhizosolenia and Bellorochea

28— 2—53	1115000	320	(Extract discolored)	3,484	15	74,333	Chaetoceros and Asterionella
11— 3—53	11400000	340		33,530	240	47,500	Chaetoceros and Rhizosolenia
24— 3—53	34500000	1200		28,750	720	47,917	Rhizosolenia Chaetoceros and Leptocylindricus
26— 3—53	22500000	800		28,125	500	45,000	Rhizosolenia Leptocylindricus and Chaetoceros
27— 3—53	5100000	780		6,538	420	12,143	Leptocylindrious and Biddulphia (Green organic matter abundant)
22— 4—53	369600000	6240		59,234	3840	96,250	Chaetoceros and Asterionella

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On Uniconvergence Spaces

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ABSTRACT

While the topology of metrisable spaces are capable of being completely described in terms of convergence of sequences of points, for more general spaces it is known that convergences of point sets indexed by arbitrary directed sets would be necessary. The spaces of uniform structure which occupy a intermediate position may be expected to have a fairly simple convergence approach. Such an approach is described in this article. The *uniconvergence* which is introduced here gives an approach from convergences of point-sets indexed by a fixed directed set to a uniform structure; and every uniform structure can be so obtained. Some related problems are also indicated.

Preface

The two fundamental methods of introducing a topological structure considered by M. Fréchet in his 'Espaces abtraites', (Fréchet, 1928), namely through a given family of convergences and through a distance function, have been generalised to deal with more general categories of spaces. For the T-spaces or Kuratowski spaces it has been shown by Birkhoff (1937) that convergences based on directed sets would be adequate to determine the topology; while A. Weil (1937) has extracted the essentials of the structure implied by a distance function in his definition of the spaces with a uniform structure. The uniform structure also leads to a certain non-topological structure, implied in the selection of a fundamental system of neighbourhoods at each point indexed by a fixed (directed) set, so that the Hausdorff axioms for neighbourhoods are uniformly satisfied. The problem seems then natural to demand if we could not also make a similar choice of the convergences at each point, choosing those that are indexed by a single directed set, in such a way that the same sort of structure as that given by a uniform structure is determined by these convergences. It is the purpose of this paper to provide such a convergence scheme, which I call uniconvergence.

The axioms of uniconvergence and their interdependence are dealt with in § 2. In § 1 the uniform structure is presented in a form suitable for our purpose. In §§ 3 and 4 the possibilities of deducing a uniform structure from a uniconvergence and vice-versa are examined. § 5 says in effect that uniconvergence gives the same sort of structure to a space as a uniform structure, and conversely; and that the directed set to be used in either case could always be reduced to a filter of subsets of $R \times R$, where R is the space in question. The last section relates metrisation with the existence of a uniconvergence over the ordered set of positive integers, proving incidentally the known result that convergences of sequences is sufficient to describe the topology of a metrisable space. Some problems related to this theory are also given at the end. These are being studied by students in the department, and would be taken up in a subsequent article.

1. *Uniform structure in R over D*

We recapitulate the definitions (in suitable form) and some of the main properties of spaces with uniform structure (Bourbaki, 1951).

R is a 'space' of 'points'; and D is a set partially ordered by a binary, reflexive and transitive relation of order $\angle$, under which D is 'directed to the right', i.e., to each pair of elements d, d' in D one can find an element d'' in D such that $d \angle d''$ and $d' \angle d''$.

By a uniform structure in R over D is meant a function $u(d, x)$ of the combinatory product $D \times R$ into subsets of R subject to the conditions:

U_1. For all d in D and x in R, $x \varepsilon u(d, x)$.

U_2. When $d \angle d'$ in D, whatever be x in R, $u(d', x) \subset u(d, x)$.

U_3. There is a mapping s of D in D such that, whatever be x, y from R and d in D, $y \varepsilon u(s(d), x)$ implies $x \varepsilon u(d, x)$.

U_4. There is a mapping t of D in D such that, whatever be x, y, z in R and d in D, $z \varepsilon u(t(d), y)$ and $y \varepsilon u(t(d), x)$ imply $z \varepsilon u(d, x)$.

A uniform structure in R (over D) determines a topology in R when we define the closure $\bar{A}$ of any subset A of R to consist of points x for which A intersects $u(d, x)$ in a non-null subset for each d in D. Under this topology R becomes a (possibly non-Hausdorff) completely regular space.

Given two uniform structures U(D) and V(E) in the same space R over two directed sets D and E, U(D) is said to be 'finer' than V(E) if there is a function d of E in D such that $v(e,x)$ contains $u(d(e),x)$ for each x in R and e in E. And the two uniform structures are equivalent if each is finer than the other. For two spaces R, S with uniform structures U(D), V(E) respectively over the directed sets D, E we can define a function f of R in S to be uniformly continuous (*w.r.t.* these uniform structures) provided a mapping d of E in D exists such that, for all x, y in R and e *in* E, $y \varepsilon u(d(e),x)$ implies $f(y) \varepsilon v(e,f(x))$. Then it is clear that U(D) is a finer uniform structure in R than V(E) if, and only if, the identity mapping of R in itself is uniformly continuous from R with the structure U(D) to R with the structure V(E).

2. *Uniconvergence in R over D*

R and D being as in the last section, we consider a *convergence in R over D* as a pair $\{x(d), x\}$ consisting of a function $x(d)$ of D in R and a single point x in R; we say $x(d)$ converges to x as a limit. A family C(D) of such convergences in R over D is called a uniconvergence in R over D if the following conditions are satisfied: (we set $x(d) \rightarrow x$, C(D), to signify that the convergence $\{x(d), x\}$ belongs to C(D).

C_1. If $x(d) = x$ for each d in D and an x in R, then $x(d) \rightarrow x$, C(D).

C_2. If $\underset{\sim}{r}$ is a mapping of D in D such that $d \angle \underset{\sim}{r}(d)$, and if $x(d) \rightarrow x$, C(D) then $y(d) \rightarrow x$, C(D), where $y(d) = x(\underset{\sim}{r}(d))$.

C_3. There is a mapping s of D in D such that, for any x, y in R, if y is near x of order $s(d)$ then x is near y of order d: where we say z is near w of order d' (d' in D; w, z in R) if there is a $w(d) \rightarrow w$, C(D) with $z = w(d')$.

C_4. There is a mapping t of D in D such that, for any functions $x(d), x_d(e)$ of D in R and any point x in R, when $x_d(e) \rightarrow x(d)$, C(D) for each d in D, and $x(d) \rightarrow x$, C(D), then $x_{t(d)}(t(d)) \rightarrow x$, C(D).

The uniconvergence is called *normal* if it satisfies the further condition:

C*. When $x(d)$ is any point in R close to x of order d, for each d in D, then $x(d) \rightarrow x$, C(D).

Using C_1 and C_4 it is easy to deduce the following:

C_5. There is a mapping t of D in D such that, whatever be x y, z in R, if z is near y of order $t(d)$ and y is near x of order $t(d)$, then z is near x of order d.

Also in the presence of C^*, one can show that C_5 implies C_4.

The following examples prove the independence of the four axioms C_1-C_4.

Ex. 1. R is the set of real numbers in the closed interval $[0, 1]$; and D is the ordered set of positive integers $(1, 2, 3, \cdots)$. We set $x(d) \rightarrow x$, C (D) if, for each d, $x(d) \neq x$ and $| x(d) - x | \angle 1/d$. Then C_1 is not true, but C_2, C_3, C_4, C^* and C_5 are seen to be true.

Ex. 2. R and D are as before. We now define $x(d) \rightarrow x$, C (D) to mean that $| x(2d) - x | \angle 1/2d$, for each d in D. Then C_2 is not true, but C_1, C_3, C_4, C^* and C_5 are verified to be true.

Ex. 3. R and D are as before. But we take $x(d) \rightarrow x$, C (D) to mean that $0 \angle$ or $= x(d) - x \angle 1/d$, for each d in D.C_3 now fails to be true; but C_1, C_2, C_4, C^* and C_5 are true.

Ex. 4. D is as before; R is the set of complex numbers of modulus $\angle$ *or* $= 1$. We set $x(d) \rightarrow x$, C (D) if $| x(d) - x | \angle 1/d$ and further either $x = 0$ or all the non-zero $x(d)$ are of the same amplitude. (So that convergence towards the origin in the Argand diagram is only along radii through the origin.) Now C_4 and C^* fail to be true, but C_1, C_2, C_3 and C_5 are true.

A uniconvergence C (D) in R determines a topology for R when we take the closure of a subset A of R to consist of the limits x of convergences $x(d) \rightarrow x$, C (D), for which $x(D)$ is a subset of A. That this makes B a completely regular space will follow from the theorem 1 of the next section.

When R has a uniconvergence C (D) over D, and S has a uniconvergence C (E) over E, we call a mapping f of R in S a uniformly continuous function of R in S (*w.r.t.* the uniconvergences) provided there exists a mapping d of E in D such that, whenever $x(d) \rightarrow x$, C (D) in R then $y(e) \rightarrow y$, C (E) in S, where $y(e) = f(x(d(e)))$, and $y = f(x)$. When R and S are the same and the identity mapping is uniformly continuous from R with the uniconvergence C (D) to R with the uniconvergence C (E) then we say C (D) is a finer uniconvergence in R then C (E). Evidently for the derived topology also one has the finer topology correspond-

ing to the finer uniconvergence. Finally two uniconvergences are called equivalent if each is finer than the other.

3. *From uniconvergence to uniform structure*

Given a uniconvergence $C(D)$ in R over D, we can define a derived uniform structure $U(D)$ in R over D as follows: $y \varepsilon u(d, x)$, for x, y in R, and d in D, if and only if y is near x of order d. In fact U_1, U_2, U_3, U_4 follow immediately from C_1, C_2, C_3 and C_5, respectively; and we observed that C_5 is a consequence of C_1 and C_4. For this derived uniform structure we have the following:

Theorem 1. The uniform structure $U(D)$ in R over D, derived from a uniconvergence $C(D)$ in R over D, determines the same topology for R as $C(D)$; further if f is a uniformly continuous function of the space R with the uniconvergence $C(D)$, in the space S with the uniconvergence $C(E)$, then f is also uniformly continuous from the space R with the uniform structure derived from $C(D)$, in the space S with the uniform structure derived from $C(E)$. In particular a finer uniconvergence in R determines a finer uniform structure and equivalent uniconvergences determine equivalent uniform structures.

Proof. $x(d) \to x, C(D)$, and $x(D) \subset A$, imply that A contains an element $x(d)$ in each $u(d, x)$; while conversely if $x(d)$ is an element of $u(d, x)$ which lies in A for each d in D, there are function $x_d(e)$ of D in R such that $x_d(e) \to x (= x_d)$ for each d in D, and $x(d) = x_d(d)$. Since $x_d \to x$ by C_1, it follows by C_4 that $x_{t(d)}(t(d)) (= x(t(d))) \to x$, $C(D)$, and these $x(t(d))$ are all in A. Hence the closure of a subset A of R is the same for the uniform structure topology as for the uniconvergence topology. The remaining assertions of the theorem follow from the definitions involved, and from the method of deriving the uniform structure from the uniconvergence.

4. *From uniform structure to uniconvergence*

Given a uniform structure $U(D)$ in R over D we can define a derived uniconvergence $C(D)$ in R over D by setting:

$x(d) \to x$, $C(D)$ if, and only if, $x(d) \varepsilon u(d, x)$ for each d in D. Then $U_1, \ldots . U_4$ imply respectively C_1, C_2, C_3 and C_5 while C^* is also an evident consequence of the method of deriving the uniconvergence. C^* with C_5 implies C_4, and so the derived $C(D)$ is a normal uniconvergence. We have the

Theorem 2. The topology defined by the derived uniconvergence C (D) is the same as the one given by the uniform structure U (D). Uniform convergence of a function from one uniform structure space to another implies that the function is also uniformly continuous when the spaces are endowed with the derived uniconvergences. In particular a finer (or equivalent) uniform structure on the same space gives a finer (or equivalent) derived uniconvergence.

Proof. If x is in the closure of A under the topology of the uniform structure U (D), every $u(d, x)$ contains some $x(d)$ in A; taking one such point in each $u(d, x)$ we get a mapping of D in R with $x(\mathrm{D}) \subset \mathrm{A}$, and $x(d) \to x$, C (D). Conversely if $x(d) \to x$, C (D) and $x(\mathrm{D}) \subset \mathrm{A}$, $x(d)$ is a point of A in $u(d, x)$ for each d in D, and so x is in the closure of A defined by U (D). Thus the topologies defined in terms of U (D) and C (D) are the same. The final statements are easy to establish remembering that the derived uniconvergences are normal.

5. *The normal forms*

We can now examine what happens when the two passages described in the last two sections are taken one after the other.

Theorem 3. (i) If U (D) is a uniform structure on R over D, C (D) the uniconvergence derived from it, and V (D) the uniform structure derived from C (D) then U (D) and V (D) are identical (i.e., $u(d, x) = v(d, x)$ for each d in D and x in X). Every uniform structure U (D) in R is equivalent to another V (E) over a directed set E which forms a filter of subsets of $(\mathrm{R} \times \mathrm{R})$, ordered by $\supset$.

(ii) If C (D) is a uniconvergence on R over D, U (D) is the derived uniform structure, and C* (D) the uniconvergence defined by U (D) then C* (D) is a normal uniconvergence equivalent to C (D); it is the same as C (D) (i.e., $x(d) \to x$ holds for either only if it holds for the other) when, and only when, C (D) is normal. Every uniconvergence C (D) is equivalent to a normal uniconvergence C* (E) over a filter E of subsets of $(\mathrm{R} \times \mathrm{R})$.

Proof. (i) $y \varepsilon u(d', x)$ implies that a $x(d)$ can be defined with $x(d') = y$ such that $x(d) \to x$, C (D), whence $y \varepsilon v(d', x)$ also. Conversely if $y \varepsilon v(d', x)$ then there is a $x(d) \to x$, C (D) such that $y = x(d')$; as C (D) is the derived uniconvergence from U (D), it

follows that $x(d') \varepsilon u(d', x)$ or, $y \varepsilon u(d' x)$. Thus U (D) and V (D) are the same.

Given U (D) we define a mapping e of D in a family E of subsets $\{e\}$ of $R \times R$ as follows: $e(d)$ is the set of (x, y) for which it is true that $y \varepsilon u(d, x)$. These sets $e(d)$ form a filter of subsets of $R \times R$ (if d, d' are $\angle d''$ in D then $e(d)$, $e(d')$ both $\supset e(d'')$). A uniform structure in R is given by setting $v(e, x)$ to be the set of y in R for which (x, y) is in e. The verification that this is a uniform structure and that it is equivalent to U (D) is simple.

(ii) We have already observed that C* (D) is a normal uniconvergence when it is derived from a uniform structure U (D). If U (D) is derived from C (D), then $x(d) \rightarrow x$, C (D) implies that $x(d) \varepsilon u(d, x)$ for each d in D, and so $x(d) \rightarrow x$, C* (D). This shows that C (D) is finer than C* (D). By C_1 & C_4, the mapping $t: D \rightarrow D$ is such that $x_d \rightarrow x$, C* (D) implies that $x_{t(d)} \rightarrow x$, C (D). Hence C* (D) is finer than C (D) also. If C (D) is normal then, $x(d) \rightarrow x$, C* (D) implies that $x(d)$ $\varepsilon u(d, x)$ or $x(d)$ is near x of order d under the uniconvergence C (D); hence $x(d) \rightarrow x$, C (D) also.

If C* (D) is the uniconvergence derived from the uniform structure U (D) derived from C (D), by (i) there is a uniform structure V (E) over a filter of subsets of $R \times R$ equivalent to U (D). The normal uniconvergence C* (E) derived from this will then be equivalent to C* (D) by theorem 2; and C* (D) is equivalent to C (D).

6. *Metrisation and other questions*

It is a well-known result that a Hausdorff space with a uniform structure over the directed set of the positive integers is metrisable; while the converse is obvious. We deduce then the

Corollary. A Hausdorff uniconvergence space is metrisable if, and only if, there is an equivalent uniconvergence over the ordered set of the positive integers.

Various questions relating to the uniconvergence spaces are yet to be settled. Two of these are:

(1) The axioms C_1, C_2, C_3 and C_5 for a family of convergences in R over D are sufficient to determine a uniform structure in R over D as described in § 3. And these do not imply C_4 or C*.

What weaker form of topological and non-topological structure do these alone lead to?

(2) The properties relating to completeness, total boundedness, etc., have to be carried over to uniconvergence spaces from the uniform spaces.

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Rhizosphere Microflora of Plants Growing in Different Ecological Habitats

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ABSTRACT

1. Results of a quantitative and qualitative study of rhizosphere microflora of plants growing in three different ecological habitats are reported.

2. Fungal, bacterial and actinomycete numbers of mesophytes were higher than those of the aquatic and marshy plants, as determined by dilution plate technique.

3. The occurrence of specific rhizosphere micro-organisms depended on the particular plant genus or species rather than the ecological habitat.

Introduction

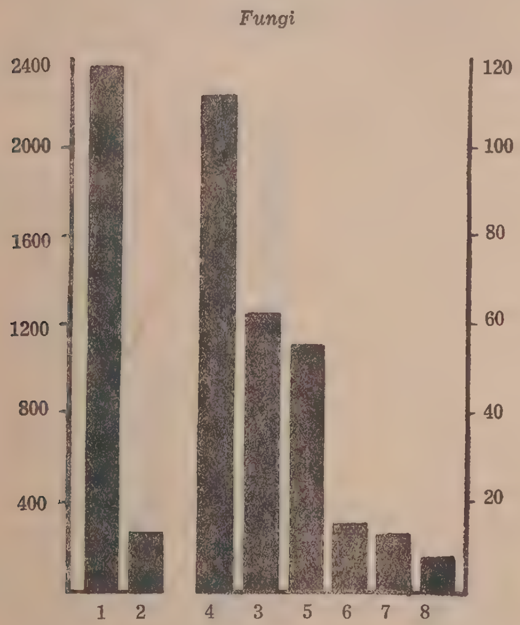
The study of rhizosphere microflora of plants in relation to different ecological habitats has received little attention, albeit considerable work on rhizosphere microflora of agricultural crop plants has been done by several workers (Harley, 1948; Katznelson *et al* 1948). Very recently Webly *et al.* (1952) have made a study of soil and rhizosphere microflora in relation to plant succession on sand dunes, which represents, however, only one ecological habitat.

In this paper are presented results of a study of rhizosphere microflora of plants growing in three different ecological habitats viz., psammophytic, aquatic and mesophytic.

Experimental

The following plants were collected for rhizosphere studies. *Launaea pinnatifida Cass.*, *Ipomoea biloba* Forsk from sandy sea shore; *Scirpus articulatus L.* and *Polygonum glabrum* Will from fresh water marsh; *Jussieua repens L.* from fresh water pond; *Avicennia officinalis L.* from the backwaters; *Croton sparsiflorus* Morung and *Acalypha indica L.* from the University

Botany Laboratory campus. Except *Avicennia*, all the others were in flower at the time of collection.



Text Fig. 1. Numbers of fungi in thousands per gram of moisture free rhizosphere soil.
Index: 1 = *Launaea pinnatifida*. 2 = *Ipomoea biloba*. 3 = *Acalypha indica*. 4 = *Croton sparsiflorus*. 5 = *Scirpus articulatus*. 6 = *Polygonum glabrum*. 7 = *Jussieua repens*. 8 = *Avicennia officinalis*.

The roots of the various plants with the adhering soil were transferred at the place of collection into sterile flasks as far as possible under aseptic conditions. The procedure followed for rhizosphere analyses was essentially the same as that given by Agnihothrudu (1953).

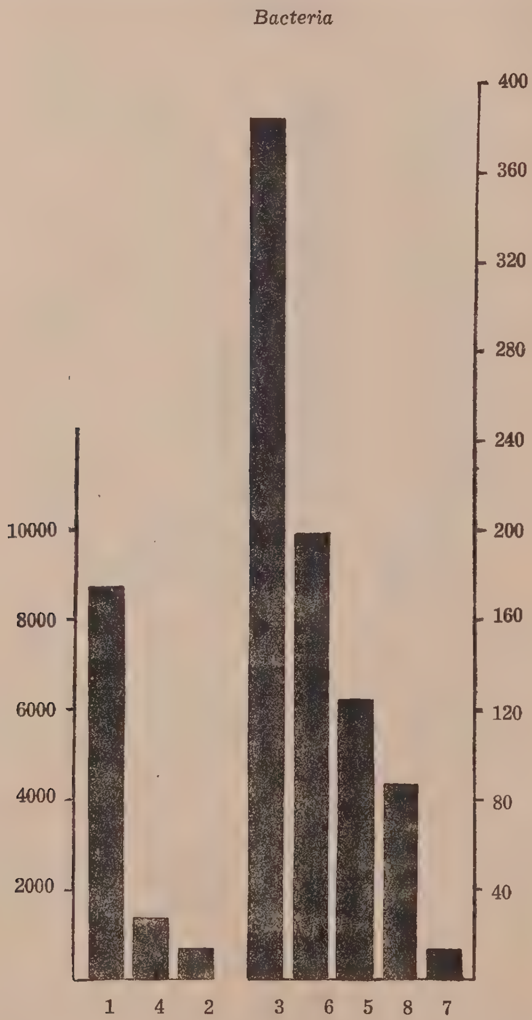
Results

Bacteria (Tables I & II. Text Fig. 2):-

Highest numbers of bacteria (8625 millions per 1 g. of rhizosphere soil) were recorded in *Launaea*, the sand plant and lowest (12·5 millions per 1 g.) in *Jussieua* which is an aquatic plant.

Actinomycetes (Tables I & II. Text Fig. 3):—

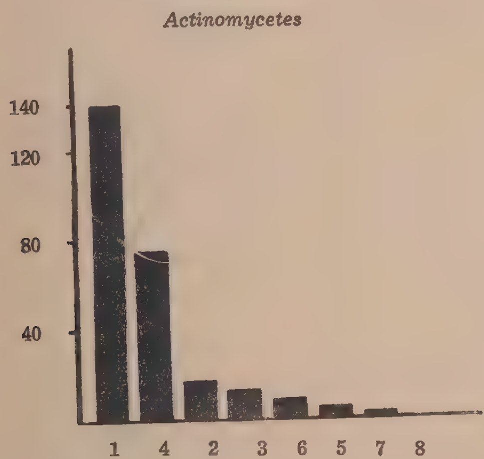
As in the case of bacteria, highest number of actinomycetes were recorded in *Launaea*, the next in order being *Croton* which



Text Fig. 2. Numbers of bacteria in millions per gram of moisture free rhizosphere soil. (Index same as in Text Fig. 1).

registered significantly higher numbers than the other plants. Although there was no significant difference between the numbers

of actinomycetes in the rhizosphere of *Ipomoea, Acalypha, Polygonum, Scripus, Jussieua* and *Avicennia* when arranged in the decreasing order of numerical magnitude, *Jussieua* and *Avicennia* which are aquatic and marshy in habitat respectively recorded low numbers of bacteria and actinomycetes as compared with other terrestrial plants studied.



Text Fig. 3. Numbers of Actinomycetes in millions per gram of moisture free rhizosphere soil. (Index same as in Text Fig. 1).

Fungi: The results are presented in Table I and the analysis of significance in Table II.

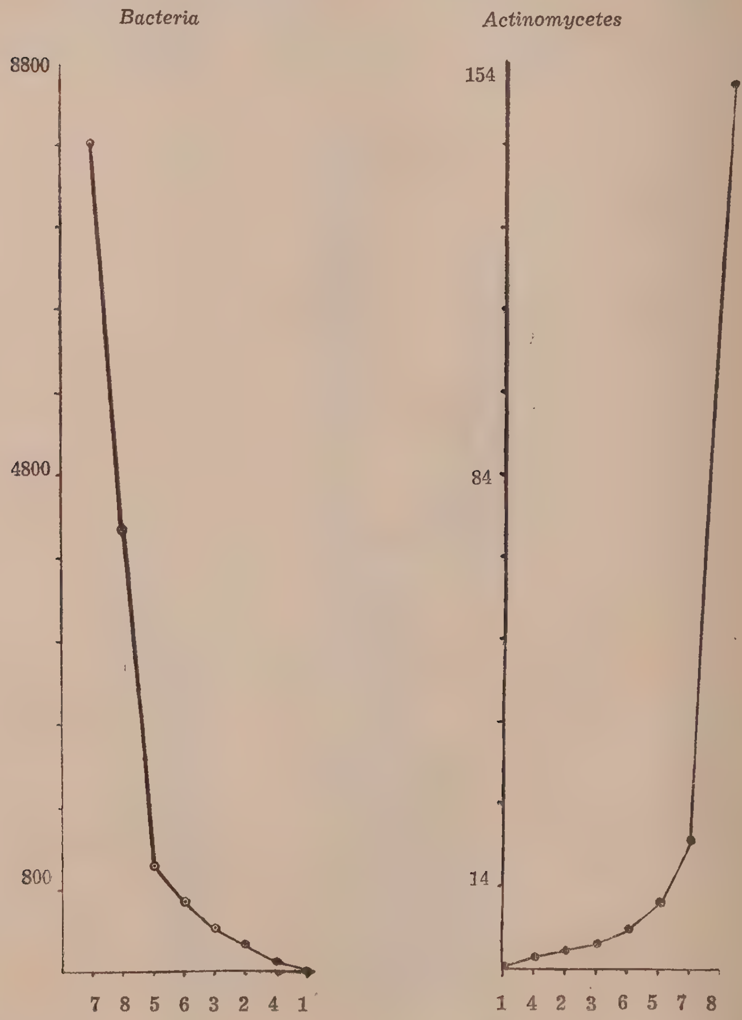
As in the case of bacteria and actinomycetes, highest numbers were recorded in *Launaea* (23·6 millions per 1 g. rhizosphere soil) and lowest in *Avicennia* (8000 per 1 g.) (Text Fig. 1).

The terrestrial plants, viz., *Launaea, Ipomoea, Croton* and *Acalypha* registered higher numbers than the aquatic plants.

Fungi in the rhizosphere:

Fungi in the dilution plates: The numbers and percentage occurrence of different fungi in the dilution plates are furnished in Table V. *Terreus* and Niger groups of *Aspergillius* and species of *Penicillium* were the most predominant (Tables III & V). Aquatic and marsh plants with the exception of *Avicennia* which is a salt water marsh plant showed a greater variety of fungi than the terrestrial plants, *Launaea, Ipomoea, Acalypha* and *Croton*. Among the

various groups of *Aspergillius,* Terreus group and Niger group were by far the most predominant. The total absence of Terreus group



Text Fig. 4. Showing the correlation between the bacterial and actinomycetes numbers in one gram of moisture free rhizosphere soil of different plants. (Index same as in Text Fig. 1).

in *Croton* and Niger group in *Launaea* and *Avicennia* is worthy of note. (Table V). All the plants showed the presence of *Penicillia* in the rhizosphere dilutions, higher percentage of *Penicillia* being

recorded in the aquatic plants (*Polygonum, Jussieua, Avicennia* and *Scirpus.*) (Tables III & V).

Fungi in root platings :

The roots of all the aquatic plants yielded greater variety of fungi than the other plants studied (Table IV. Text Fig. 4).

The aquatic plants registered higher percentage occurrence of *Penicillia* than the terrestrial plants, an observation similar to that in the dilution plates.

Higher percentage occurrence of Fusaria was recorded in the two mesophytes (*Acalypha* and *Croton*, 80 and 100% respectively). This fungus was completely absent in sand plants (*Launaea* and *Ipomoea*) and in the back water marsh plant *Avicennia* (Text Fig. 4). The roots of *Croton, Scirpus, Polygonum* and *Avicennia* yielded *Trichoderma viride* Pers. ex Fr. (97, 31, 20, 19% respectively).

The following were the other fungi recorded.

Curvularia lunata (Wakker) Boedijn,

Rhizopus nodosus Namyslowski,

Syncephalastrum racemosum (Cohn) Schroeter,

Cladosporium herbarum (Persoon) Link,

Cunninghamella elegans Lendner,

Chaetomium bostrychodes Zopf,

Thielavia basicola Zopf,

Gliocladium fimbriatum Gilman and Abbott,

and species of *Diplodia, Phoma, Mucor, Helminthosporium;* and two ascomycetous fungi of which one was tentatively identified as *Chaetoceratostoma* Turconi & Maffei.

Discussion

In the present work an attempt has been made to study the rhizosphere microfloras of plants growing in three different ecological habitats namely, psammophytic, mesophytic and aquatic. Considering the quantitative nature of the bacterial and actinomycetes flora of the rhizosphere the aquatic plants recorded com-

Text Fig. 5. Percentage occurrence of fungi in the root platings of different plants. (Index same as in Text Fig. 1).

paratively lower numbers than either the mesophytes or psammophytes. (Table I). There is a direct correlation between the numbers of actinomycetes and bacteria: the rhizospheres of plants recording higher numbers of bacteria correspondingly registering increased number of actinomycetes (Tables I & II. Text Figs. 2, 3 and 4). The complete absence of actinomycetes in the rhizosphere dilutions of *Avicennia,* a back water marsh plant is most probably due to their limited ocurrence in such a habitat (Waksman, 1950) (Tables I, II & III. Text Figs. 3 and 4). The higher number of fungi observed in the psammophytes, and mesophytes and considerably lower numbers in the aquatic plants may be attributed to better aeration in the former than in the latter. Higher percentage occurrence of Fusaria in the root plantings of mesophytes (*Croton, Acalypha*), as compared with others and its total absence in the psammophytes (*Launaea, Ipomoea*) and low percentage occurrence in aquatic plants were interesting features. Similarly, *Macrophomina phaseoli* was absent in aquatic plants with the exception of *Scirpus* where its percentage occurrence was negligible. (Text Fig. 5).

The investigation emphasises that the occurrence of specific rhizosphere micro-organisms depended largely on the individual plant species or genus irrespective of the ecological habitat in which they grow.

ACKNOWLEDGEMENTS

We thank Professor T. S. Sadasivan and Dr. C. V. Subramanian of the University Botany Laboratory for their helpful criticism and suggestions in the preparation of this paper.

TABLE I

	Launaea	Ipomoea	Acalypha	Croton	Scirpus	Polygonum	Jussieua	Avicennia
* Fungi	23550	2550	625	1125	555	153	130	80
† Bacteria	8625	622·5	380	1267·5	125	197·5	12·5	95·3
† Actinomycetes	140	17	12·5	75	4·5	8	0·8	0

* in thousands } per 1g. of moisture free rhizosphere soil.
† in millions }

TABLE II

Table of significance for microbial numbers in the rhizosphere	..	1 = Launaea
		2 = Ipomoea
Fungi : 1, 2, 4, 3, 5, 6, 7, 8	..	3 = Acalypha
		4 = Croton
Bacteria : 1, 4, 2, 3, 6, 5, 8, 7	..	5 = Scirpus
		6 = Polygonum
Actinomycetes : 1, 4, 2, 3, 6, 5, 7, 8	..	7 = Jassieua
		8 = Avicennia

TABLE III

Showing the percentage occurrence of different fungi in the rhizosphere dilution plates

Plants		Aspergilli %	Penicillia %	Other fungi %
Launea	..	99·48	0·26	0·26
Ipomoea	..	84·90	3·30	11·90
Acalypha	..	20·00	30·00	50·00
Croton	..	67·70	20·00	13·30
Scirpus	..	37·10	55·07	7·83
Polygonum	..	39·26	50·00	10·74
Jussieua	..	54·37	21·70	23·93
Avicennia	..	66·67	33·33	

TABLE IV

Table showing the number of genera of Fungi and groups of Aspergillus recorded in the rhizosphere of plants both by the dilution plate and root plating techniques.

Plants		Dilution	Plate	Root	
		number of Genera	Aspergillus groups of	number of Genera	Groups of Aspergillus
Launea	..	3	4	6	3
Ipomoea	..	3	4	9	4
Acalypha	..	4	2	5	4
Croton	..	3	4	6	3
Scirpus	..	5	5	10	4
Polygonum	..	5	4	10	2
Jussieua	..	6	5	6	1
Avicennia	..	2	3	8	6

TABLE V

Table showing numbers of fungi in thousands, and the percentage occurrence in 1 gm. of moisture free Rhizosphere Soil

	Groups of Aspergillus						Other Fungi							
	Terreus	Flavus	Nidulans	Fumigatus	Candidus	Niger	Penicillia	Trichoderma	Syncephalastrum	Phoma	Alternaria	Curvularia	Myrothecium	Sterile Forms
Launea														
Numbers ..	18228	61	—	61	5077	—	61	61	—	—	—	—	—	—
Percentage ..	77·4	0·26	—	0·26	21·56	—	0·26	0·26	—	—	—	—	—	—
Ipomoea														
Numbers ..	1913	—	84	—	84	84	84	—	—	—	—	—	—	3010
Percentage ..	75	—	3·3	—	3·3	3·3	3·3	—	—	—	—	—	—	11·8
Acalypha														
Numbers ..	94	—	—	—	—	31	188	—	—	125	—	—	—	188
Percentage ..	15·0	—	—	—	—	5·0	30·0	—	—	20	—	—	—	30
Croton														
Numbers ..	—	150	—	75	225	300	225	—	—	—	—	—	—	150
Percentage ..	—	13·3	—	6·7	20	26·7	20	—	—	—	—	—	—	13·3
Scirpus														
Numbers ..	120	—	9	·2	13	62	306	5	—	—	—	2	—	36
Percentage ..	21·62	—	1·67	0·34	2·34	11·13	55·7	0·99	—	—	—	0·34	—	6·5
Polygonum														
Numbers ..	27	8	—	3	—	22	77	3	3	—	—	—	—	11
Percentage ..	17·86	5·3	—	1·8	—	14·3	50	1·8	1·8	—	—	—	—	7·14
Jussieua														
Numbers ..	11	3	8	25	—	23	28	3	—	—	3	—	3	23
Percentage ..	8·7	2·17	6·51	19·57	—	17·42	21·17	2·17	—	—	2·17	—	2·17	17·42
Avicennia														
Numbers ..	27	—	9	—	18	—	27	—	—	—	—	—	—	—
Percentage ..	33·33	—	11·12	—	22·22	—	33·33	—	—	—	—	—	—	—

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Seasonal Fluctuations in the Fat Content of the Prawn *Penaeus Indicus* M.Ed.

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ABSTRACT

The seasonal fluctuations in the fat content of the prawn *Penaeus indicus* are studied. / Four different arbitrary length groups were chosen and the fluctuations in the fat content during the course of a year estimated. It is seen that in the highest length group (groupIV) the percentage of fat is greatest and also the maximum percentage of fat occurs during the period November-January in all the length groups.

The percentage of fat stored appears to be nearly the same in prawns of both the sexes.

The relationship between the fat content and feeding habits of the prawn is surveyed.

Introduction

Although in recent years considerable attention has been given to estimation of fat values of fishes (Hickling, 1947; Patakoot *et al.*, 1950; Sekharan, 1950; Chidambaram *et al.*, 1952; Venkataraman and Chari, 1953) the commercially important penaeid prawns, with a few exceptions, have not been studied from the above point of view. From a study of the chemical composition of prawns, Appanna and Devadatta (1942), Chari (1948) and Gopalakrishnan (1951) have shown that as in fishes the fat constitutes a food reserve along with proteins. Further, it has been shown by Koyama (1929) that doubly refracting fat is present in all organs except the heart and blood vessels of *Penaeus japonicus*. It is generally known that the fat content of animals is subject to periodic quantitative fluctuations in the tissues. But the workers in the field are not agreed as to the factors which cause such changes. This is especially so in the case of fishes, which have been studied in regard to the seasonal fluctuations in stored fat and various suggestions have been made as to contributing causes for such

changes. Temperature of the external medium was shown to influence the fat content of some fishes by Johnstone (1914, 1917), but this view has been denied by Dixon (1937) for sprats from Norway. Age is another factor suggested by Bruce (1924), Lovern (1938) and Wilson (1939). Johnstone (1917), Greene (1919) and Bull (1928) thought that the maturation of gonads and spawning season have a direct influence on the amount of fat present. Channon and El. Saby (1932), Lovern and Wood (1937), Dixon (1937), Wilson (1939) and Hickling (1947) were able to demonstrate relations between food and intensity of feeding on the one hand and the quantitative changes in fat content on the other. In view of the lack of information as to the fluctuations, if any, in the fat content of prawns and to see if the same causes that account for such changes as in the fishes also operate here, the fat contents of the prawn *Penaeus indicus* collected in different months of the year are estimated and studied in the present work.

Material and methods

The prawns used in the following study were collected from the sea and the brackish water areas of the Cooum river. Fat estimations of different length groups were made during the course of a year. For the purpose of this study the prawns studied were divided into four different length groups as follows: Length group I. Length below 11 cms., Length group II. Length between 11 and 14 cms., Length group III. Length between 14 and 17 cms., Length group IV. Length between 17 and 20 cms.

Chemical extractions of fat were made using both male and female prawns of different sizes collected from both the localities mentioned above. For each extraction, the following procedure was adopted. About three or four specimens belonging to the same sex, length group and locality were isolated from the collections obtained from the nets. The whole prawn except the stomach and its contents was used for the fat estimation. The specimens chosen were cut into small spieces and then minced thoroughly in a meat mincer, until a pulp of the tissue was obtained. The whole quantity of minced tissue was mixed in a clean porcelain mortar and enough quantity was taken in a glass dish and weighed. This was then dried in a constant temperature apparatus at 105°C. until all traces of moisture disappeared. For the estimation of fat present in this dried tissue, a Soxhlet extraction apparatus was used. The solvent in the flask, ether sulphuric, was heated by an electric heater provided with a regulator, and ice-cooled water was circu-

lated in the condenser of the apparatus. In the first few experiments the process of extraction was carried on till the weight of the flask with the extract was constant for successive periods. Later it was noticed from the results of the first experiments that continuous extraction for seven hours was enough to isolate all the fat present. That this is so was confirmed by extraction of the residual tissue present in the thimble to detect the presence of any fat left unextracted and in all cases the results were negative.

It is known that the fat thus extracted may contain slight amounts of other substances dissolving in ether (Sherman, 1941). However, ether is the best solvent for fat and hence some authors designate the material extracted by ether as "ether extract" rather than as "fat". The term "fat" itself is used in this paper, as the amount of other substances that may be present along with it are considered negligible.

The histological technique as adopted by Wilson (1939) for studying the distribution of fat in fishes was tried, but was not successful, as such well marked regions of fat storage could not be made out in the sections of prawns.

Length groups and their fat values in different months.
Fat content of marine prawns.

Prawns of all the four different length groups were available from the fishermen's nets during the major part of the year. The fat values of prawns of the different length groups are shown in Figs. 1 and 2.

(*a*) *Length group I.*

In Fig. 1 the fat values obtained for males during the various months are plotted. The percentage is seen to be low in August and continues to be so till November, after which there is a rise during December. In March the value decreases and only slightly higher percentages are noted during the following months of April and May. In the female specimens (Fig. 2) the fat values are more or less similar to those obtained for the males. The fat content percentage is low in August, but rises steadily till December when the peak value of about 1·3% is reached. A fall in percentage content occurs by February after which the value is more or less stationary. Minor variations from the normal do not affect the overall trend of the graph.

(b) *Length group II.*

Similar fat estimations were made for prawns of length between 11 and 14 cms. Sexes were examined separately and extractions were made during all the months except September and February. The number of specimens studied and their average fat

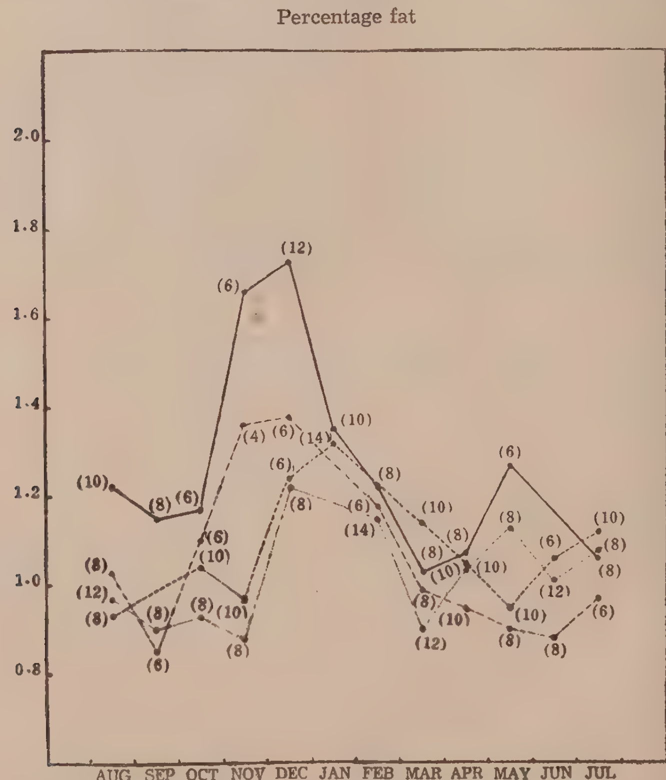

Fig. 1. Percentage fat content of the four length groups of *Penaeus indicus* (males: marine) in different months.
Figures in brackets indicate no. of specimens studied.

Length gr. I
Length gr. II
Length gr. III
Length gr. IV

percentages are shown in Figs. 1 and 2. The amount of fat present in prawns of this length group show that the percentage values correspond with those for the smallest length group. It will be noted from Figs. 1 & 2 that the maximum amount of fat occurs during the months of December and January.

(*c*) *Length group III.*

As in the smaller specimens, seasonal fluctuations in the fat content are obvious in these prawns also and it will be noted that the maximum amount of fat is present during the months of November and December, in the males as well in the females (Figs. 1 and 2). It may also be mentioned that the percentage values are approximately the same for the two sexes.

(*d*) *Length group IV.*

This length group consists of prawns of the biggest size usually obtainable from the nets and they were available for the present

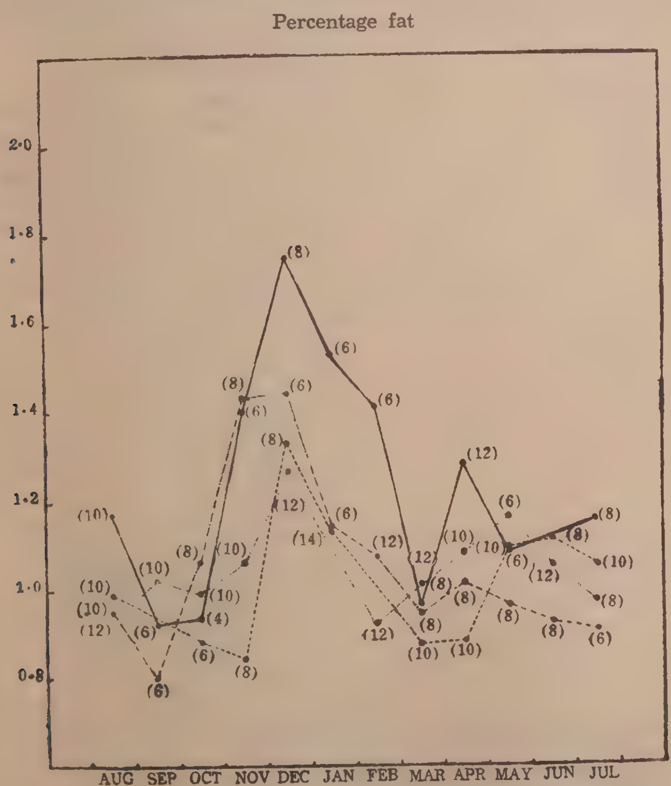

Fig. 2. Percentage fat content of the four length groups *Penaeus indicus* (females: marine) in different months. Figures in brackets indicate no. of specimens studied

Length gr. I
Length gr. II
Length gr. III
Length gr. IV

study during all the months except June. The average fat contents of these large prawns during the various months are shown in Figs. 1 and 2. It appears that the percentage of fat present in prawns of this length group is comparatively more than in the smaller forms. For the males, during the months of August, September and October the fat values are low, but in November and December very high percentages are obtained. After December, the value decreases till March and further fluctuations are not pronounced. In the female specimens also the fat value is found to be highest during December, the percentage being about 1·8.

It is interesting to note from the results obtained that in all the length groups studied the highest fat values are recorded dur-

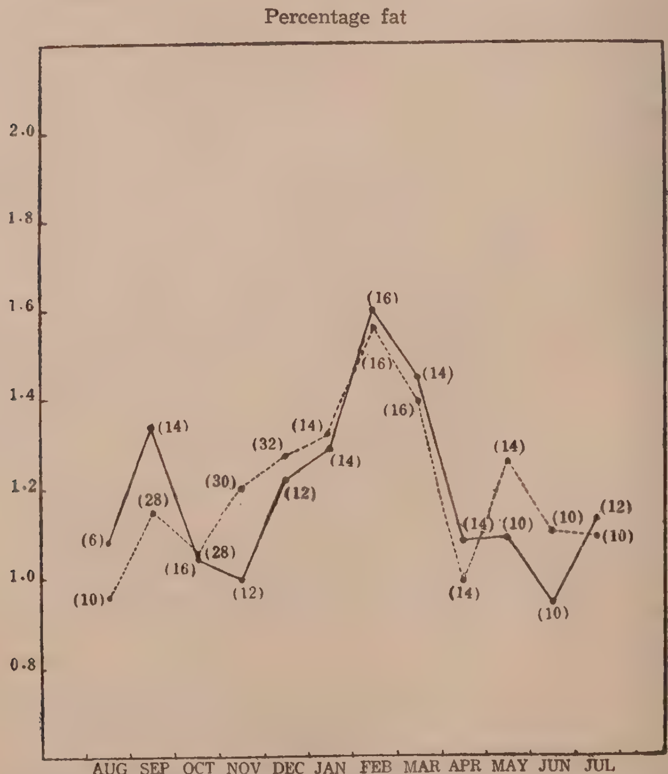

Fig. 3. Percentage fat content of brackish water *Penaeus indicus* (both sexes: length gr. I) in different months.
Figures in brackets indicate no of specimens studied.

Male
Female

ing the season comprising the months November, December and January and that the seasonal fluctuations are more or less similar for prawns of both sexes.

Fat content of prawns collected from the Cooum river.

Only smaller specimens were available from this brackish water area and hence all the specimens used for the fat estimations were young forms, of length group I. Fat estimations were made during all the months, taking the sexes separately. The number of prawns used and the results obtained from the extractions are given in Fig. 3. The graph shows that there is a great similarity in the amount of fat stored in prawns of both sexes during most of the months. Slight differences are noticed during September, November, May and June, but the significance of these differences is not clear. In the male specimens there is a decrease in fat content from September to November, after which higher values are obtained January, February and March. It appears that in the case of the female specimens, the fat content is low in August, but increases gradually and steadily till February when the highest value is reached. Afterwards there is a decrease up to April and although there is a slight rise in May, the value is low in June and July. It will be noted that in both the sexes the highest fat percentage is found during February.

During certain months prawns of length group II were obtained in the collections, but they were not used for the present study as such forms were not available throughout the year.

Distribution of fat in the prawn

Storage of fat in *Penaeus indicus* is confined mainly to the hepatopancreas, gonads and certain muscles. Sections of these tissues cut with a freezing microtome were stained in Sudan III and Scarlet Red, and examined under the microscope to study the fat storage. It is known that in decapods the hepatopancreas is the principal storage organ for reserve fat (Yonge, 1924) and that the amount of fat stored in the organ is closely related with the moulting (Paul and Sharpe, 1919; Yonge, 1924). In a section of the hepatopancreas of *Penaeus indicus* fat globules are observed in the tubules and in the small vacuoles present in the absorptive cells. They are never seen in the secretory cells of the digestive gland.

Sections of the ovary of the prawn show the presence of fat globules deposited in the "nutritive cells" surrounding the radially arranged strings of ova. The amount of fat present in the testis

is very little and is seen as small droplets in the central lumen of the lobule.

The abdominal muscles of the prawn also contain small quantities of fat, the amount being much less compared to that in fishes. A transverse slice through the anterior part of the abdomen of the animal is taken as typical for the amount of fat present in the muscles. The flexor muscles of the abdomen show the presence of very small fat globules. These globules are deposited in between the muscle fibres and are in the form of fat storing cells provided with fine enclosing membrances. Fat droplets are usually seen in the fibres of the extensor muscles of the abdomen also. In addition to these, small fat globules occur in between the abdominal cuticle and muscles.

Food of Penaeus indicus

An analysis of the stomach contents of *Penaeus indicus* (Gopalakrishnan, 1952) shows that both vegetable and animal matter are taken in right through the year and the animal matter in which crustacean and non-crustacean items can be recognised varies in composition. The fluctuations in the relative amounts of non-crustacean and crustacean constituents of the diet were followed during the different months of the year for the prawns of different sizes (Gopalakrishnan, *loc. cit.*)

Discussion

It has been shown that in fishes the amount of fat stored in the tissue depends on the quantity and quality of food taken by the fish (Channon and El. Saby, 1932; Lovern and Wood, 1937; Dixon, 1937; Hickling, 1947; Sekharan, 1950; Chidambaram, *et al.,* 1952). In the present study on the seasonal fluctuations in the fat content of the prawn, it is noticed that the maximum percentages of fat occur during the months of November, December and January. The analysis of stomach contents shows that a greater proportion of non-crustacean food elements, such as lamellibranchs, fish larvae, etc., are consumed during the above months. This is suggestive of the fact that non-crustacean food elements are productive of more fat. It is probable that in an animal like the prawn, whose dietary includes different types of food materials, the composition may affect the fat income to a greater extent than in fishes, where usually there is not that variety of the food items. It has been shown that the fluctuations in the amount of stored fat can be

related to the changes in the composition of the diet of fishes (See Hickling, 1947; Sekharan, 1950). When the fish consumes vegetable matter and non-crustacean forms (excepting teleosts), the quantity of fat present is much less than when it consumes crustacean and teleostean food items (Sekharan, unpublished thesis). It is possible that further detailed analysis of the stomach contents of the prawn and experiments on its diet may show a similar relation between the food and fat content of the prawn as well.

It will be noted from the data presented that prawns of the highest length group are found to have more percentage of fat than those of shorter length groups. This increase in the amount of fat stored may be attributed to their greater intake of food. Similar increases in fat contents due to length and also age has been reported in some fishes also (Bruce, 1924; Lovern, 1938; Wilson, 1939).

It is evident that the hepatopancreas, the female gonad and the abdominal reflexor and extensor muscles are the chief organs of fat storage in *Penaeus indicus*. It is possible that these organs show a fluctuation in fat storage corresponding to the seasonal changes in the total fat content of the prawn. Detailed analysis of the different parts of the prawn, such as liver, gonad and muscles, during the different seasons of the year and in the immature and mature forms may reveal an intricate adjustment of the total amount of fat not unlike what is found in the fish (Ramaswamy, unpublished paper).

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